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October 1985

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ENERGY SURVEY IN ZAMBEZI.
REPORT FROM A STUDY IN ZAMBIA - 1985

John M. Christensen

Abstract: The report presents the results and experiences from a field study in Zambia. The energy situation is described in detail. Energy consumption is analyzed by end-use and source. The supply situtation for the different sources - firewood, charcoal, kerosene and electricity is presented and the available local and renewable resources are outlined.
The household sector is divided into subsectors and the relation between income level and the choice of energy source is studied in detail.

EDB-descriptors: DOMESTIC SUPPLIES; ENERGY ANALYSIS; ENERGY CONSUMPTION; ENERGY SOURCES; ENERGY SUPPLIES; RURAL AREAS; ZAMBIA.

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CONTENTS

Abbrevations used

DOE	Department of Energy
MPTC	Ministry of Power, Transport and Communications
NEC	National Energy Council
UNIP	United National Independence Party
UNZA	University of Zambia
ZESCO	Zambia Electricity Supply Corporation Ltd.
ZIMCO	Zambia Industrial and Mining Corporation Ltd.
ZNEL	Zambia National Energy Ltd.
UNDP	United Nations Development Programme

Currency equivalents

(kwacha) k 1.00 = 100 n (ngwee)
k 1.00 = 5.00 D.kr. (April 1985)

PREFACE

This report is the preliminary presentation of the results and experiences obtained during a study in Zambia from 19/4 to 22/6 1985.

The study is one of the major parts of the Ph.D. project - Methods for Assesment of Energy Projects in Developing Countries - currently being performed by the author at the Systems Analysis Department, Risø National Laboratory, in collaboration with the Technical University of Denmark.

This study, as well as the rest of the Project, is organized in close collaboration with the Department of Energy in Lusaka, Zambia, where the Rural and Household Energy Development Section has integrated the project in its plans. Silvester Hibajene from the section participated in the 3 weeks of data collection in the district of Zambezi.

Besides funding from Risø, the trip was kindly supported by the Danish Council for Scientific and Industrial Research.

1. INTRODUCTION

This report presents the data collected mainly on the district level but also the essential data on the national energy situation in Zambia. In addition it describes how the study was performed. It is not the intention at this stage of the project to perform any indepth analysis of the data, but in chapter 6 there is a discussion of the limitations on the study and the uncertainties on the data, and in Appendix G the household energy consumption is analyzed.

Chapter 2 presents the background of the study and the collaboration with the Department of Energy. In chapter 3 there is a short introduction to Zambia, the Zambezi district and the present energy situation for the nation as a whole. Chapter 4 is a description of the work procedure and the considerations on methodology e.g. use of questionaires. The main results from the field study in Zambezi are presented in chapter 5 with details in the appendices and in chapter 6 the results and methods are submitted to a critical review.

2. BACKGROUND

2.1. Project collaboration

The Ph.D. project was started at Risø in August 1984 and deals with the examination of appraisal and evaluation methods applicable to energy projects in developing countries, especially projects concerning new energy technologies for rural areas without connection to central distribution systems.

Almost from the beginning of the project a contact has been es-

tablished with the Department of Energy (DOE) in Zambia through a Danish adviser working in the DOE on a Danida contract. This contact is further strengthened by the presence of a member of the Systems Analysis Department, who started on a two year contract as special adviser in DOE in November 1984.

Because of this close contact it was decided at an early stage in the project to concentrate the necessary case-studies to Zambia and in order to get sufficient depth only one rural district should be studied in detail.

2.2. Selection of district

In January 1985 a preliminary desk survey was performed by DOE. Because of the possibilities for combining a study of a decentralized electricity system with the study of traditional rural energy consumption patterns, it was decided to choose the site among four possible districts in the Northwestern Province. The distinctions between the four places were minor from an energy point of view and the main reasons for choosing Zambezi were the possibilities for local participation and accommodation during the study.

2.3. Objectives of the study

The following co-ordinated purposes were identified for the trip to Zambia:

- to strengthen the established collaboration with the DOE and establish contact with other relevant institutions
- to collect data on both national and district level and prepare any additional data collection
- to obtain the necessary insight into the rural society both in general and specifically within the energy field

- evaluation of possible future energy technologies considering the various constraints from society and economy

- discussion of methods and models applicable to project analysis.

The best time of year for the field trip to Zambezi was identified as May due to weather conditions and preferences by the local contacts. To get the necessary time for preparations, follow up and the national data collection, it was decided that the total study should be from the 20th of April until the 22nd of June.

2.4. Preparations

Beside the more general preparations and the study of already available information on Zambia and its energy situation, it was agreed that DOE should contact the local authorities in Zambezi (see Appendix B), School of Engineering at the University of Zambia, Zambia Electricity Supply Corporation (ZESCO) and arrange the co-operation with the people in Zambezi from the Danish Volunteer Service, who had agreed to assist with accommodation.

3. INTRODUCTION TO ZAMBIA

3.1. National data

The Republic of Zambia lies inland within latitutes 8 to 18 south in the southern part of Africa sharing borders with no less than 8 countries (Tanzania, Zaire, Angola, Namibia, Botswana, Zimbabwe, Mozambique, and Malawi). It gained independence on October 24, 1964, and is a one-party participatory

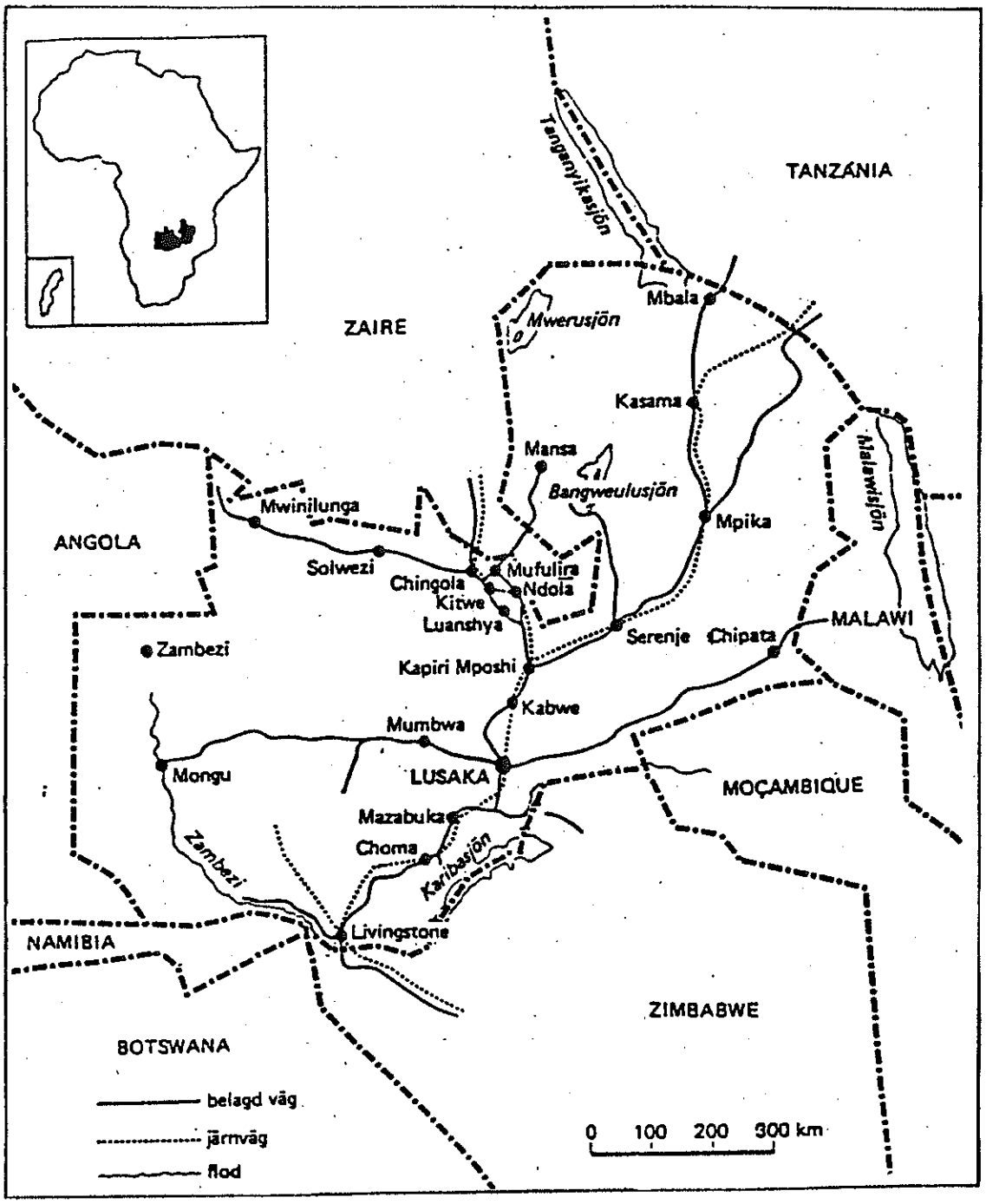


Fig. 3.1. Map of Zambia

Source: SIDA

democracy with the United National Independence Party (UNIP) as the only legal one; its leader Kenneth Kaunda has been president since independence.
As a short introduction to the Zambian society a small amount of basic data is presented (sources are listed as references).

3.1.1. Geography, climate etc.

Zambia is located on the interior African plateau with an average altitude of around 1120 m. The climate is cool tropical with three main seasons:

- cool and dry (April - August) 10 - 25°C
- hot and dry (August - November) 20 - 35°C
- warm and wet (November - April) 15 - 30°C.

The annual number of sunshine hours is between 2600 and 2900 and the mean annual rainfall between 1000 to 1500 mm in the northern half of the country and 500 to 1000 mm in the rest.

The vegetation is dominated by woodlands (> 70%) especially the Miombo woodlands which covers about half of the country. The other important type of vegetation is the grasslands representing about 20% of all land, while the remaining 10% is divided between closed forest (6%), bush and swamps (3%), other areas (1%) (see Appendix E). Only about 5% of all land is cultivated, another 5% is arable but up to 40% is considered potentially cultivable.

3.1.2. Area and population

Land area	752,600 km^2
Population (1980)	5.6 million
Population density	7.5/km^2
Population growth rate (annual average 1980-82)	3.1%
Urban population (1980)	2.4 mio.
Growth rate (1969-1980)	6.7%
Rural population (1980)	3.2 mio.
Growth rate (1969-1980)	1.1%
Urbanization (1983)	45%

Principal towns (population in 1980)		
Lusaka (capital)		538,500
Kitwe		315,000
Ndola		282,500
Languages:	Major African languages: Bemba, Nyanja, Lozi, Tonga, Kaonde, Luvale, and Lunda. Official language: English.	
Minorities: (1974)	Europeans	29,000
	Asians	16,000

3.1.3. Vital statistics (for the African population)

Crude birth rate (per '000)	48
Crude death rate (per '000)	17
Natural increase (1980-82)	3.1%
Population "doubling time"	22 years
Population projected to the year 2000	11-12 mio.
Infant mortality (per '000)	105-127
Total fertility rate (av. number of children/woman)	6.9
% Population under the age of 15/over the age of 64	48/3
Life Expectancy at birth women	50
- - - - men	47
Sex ratio (men/women): National	96.2
Urban	104.0
Rural	91.0

3.1.4. National economy

	1978	1981	1982
National income			
Gross Domestic Product (GDP)			
at current prices (K'million)	2,240	3,449	3,564
at 1970 prices (K'million)	1,484	1,484	1,454
Per capita GDP			
at current prices (K)	418	588	589
at 1970 prices (K)	277	253	240

	1978/79	1981/82
Growth rate GDP (%)	-7.7	-2.0

	1978	1981	1982
Sectoral contribution to GDP			
agricultural sector			
K'million (1970 prices)	169.2	180.0	159.0
%	11.4	12.1	10.9
Mining and quarrying			
K'million (1970 prices)	494.1	433.3	433.4
%	33.3	29.2	29.8
Manufacturing			
K'million (1970 prices)	159.6	180.0	173.0
%	10.8	12.1	11.9
National income			
at current prices (K'million)	1,809	2,917	2,881
at 1970 prices (K'million)	1,326	1,368	1,328
Per capita national income			
at current prices (K)	338	497	477
at 1970 prices (K)	248	233	219

Income distribution

	Year	%Rural	%Urban	%Total
Households with incomes (in cash or kind) below a minimum basic needs level of K100 per month	1980	80	25	60
Share of income of the poorest 40% of the population	1974	12	14	8
Share of income of the richest 5% of the population	1974	25	28	35

Foreign trade

Main exports (1982): Copper (90%), cobalt (3%), lead & zinc (3%), other (4%).

Main imports (1980): Mineral fuels (22%), chemicals (12%), basic manufactured goods (20%), machinery and transport equipment (35%), other (11%).

Experimental charcoal stoves - UNZA

	1980	1981	1982	1983
Terms of trade index (1970=100)	41	32	22	26
Exchange rate (US $ per Zambian kwacha)	1.26	1.15	1.07	0.78
Cost of living index (1975=100)	196	220	249	316
Annual increase in the cost of living	12%	12%	13%	27%

3.2. National energy situation

Zambia like most African countries is in a situation where energy supply has gained importance through the last decade. The main reasons are the rise in oil prices, which has caused increasing import bills, and the recognition of increasing deforestation especially around the urban centers, which causes difficulties in getting the necessary woodfuel supply for household consumption.

Table 3.2.1. Sectoral pattern of energy consumption (1980/81)

Sector	Petroleum	Coke	Coal	Electricity	Woodfuel	Bagasse
	%	%	%	%	%	%
Mining	37	100	52	73	6	-
Industry	18	-	48	17	-	100
Transport	35	-	-	-	-	-
Agriculture	1	-	-	2 [1)]	-	-
Others (including households)	9	-	-	8	94	-
Total	100	100	100	100	100	100

1) Many agrobased industries are registered as "industry" sector e.g. sugar, coffee etc.

Source: 1. Zambia National Energy Limited (ZNEL).
2. Department of Forestry and ZESCO.
3. UNDP (7)

Looking at the sectoral pattern of energy consumption it is obvious that the mines (almost entirely copper mines) are the dominant users of fossil fuels and electricity. Because almost all electricity is produced by hydropower, and coal comes from the Zambian mine in Maamba, a major effort has been devoted to substituting petroleum consumption by these two resources especially in mining and industry. Up till now this strategy has achieved only limited success because of the large investments required. The other major petroleum using sector is transport, and virtually nothing has been done in this sector to reduce consumption. Substitution by ethanol has been discussed in combination with plans for domestic production facilities, but the idea has apparently no real economical possibilities for attaining success.

Although woodfuel is not as dominant an energy source in Zambia as in many other African countries, Table 3.2.2 shows that woodfuel covers around 50% of the total demand. Uncertainties on the woodfuel figures are large and different statistical sources present different estimates, but it seems realistic to expect around 50%. Woodfuel is consumed mainly by rural and low-income urban households. Due to the very low population density in the rural areas only villages lying around the townships are beginning to suffer from deforestation. The deforestation is much more marked around the large urban centers, where woodfuel supply is facing larger and larger difficulties e.g. in Lusaka where charcoal is brought to the market from a distance of 50 to 150 km, which results in high prices on the charcoal. There is a growing awareness of the situation but no easy solutions exist. Activities aimed at introducing more efficient charcoal production methods and better charcoal- and woodstoves have been started on a research basis, plantation projects have been planned and research into the use of briquetted coal waste from Maamba Collieries is under way. It is a very slow process, however, due to the manpower shortages and difficulties in raising the necessary funds for the activities.

Table 3.2.2. Energy demand by source 1981

Source	'000 TJ [1]	%
Imports		
Petroleum	31.5 [2]	16.7
Coke	2.5	1.3
Sub total	34.0	18.0
Indigenous		
Hydropower	57.5 [3]	30.4
Coal	11.5	6.1
Bagasse	2.0	1.1
Woodfuel: charcoal and firewood	84.0 [4]	44.4
Total	189.0	100.0

1) 1 TJ = 23,78 TOE.

2) Including exports and refinery fuel own-use/loss.

3) Excludes exports to Zimbabwe

4) Based on 0.85 m^3 per capita consumption; and a conversion factor of 0.3 TOE per m^3 of wood.

Sources: Zambia Economic Report 1980: Indeni Refinery, ZNEL. UNDP (7)

3.3. Energy administration

Due to the mentioned increasing importance of the energy sector the Government in 1980 decided to establish a National Energy Council through an act of Parliament to advise on key issues of energy policy. Because the Council's function is that of an independent adviser to the Government, it was decided in 1981-82 to establish an energy planning unit within the Ministry of Power, Transport and Communications (MPTC) as a separate Department of Energy (DOE). Besides being the operational tool for MPTC in energy matters and dealing with the day-to-day inquiries, DOE is engaged in national energy planning, project formulation and evaluation, industrial energy management, rural and household energy development etc.

Figure 3.4.1. Provinces and Districts of Zambia

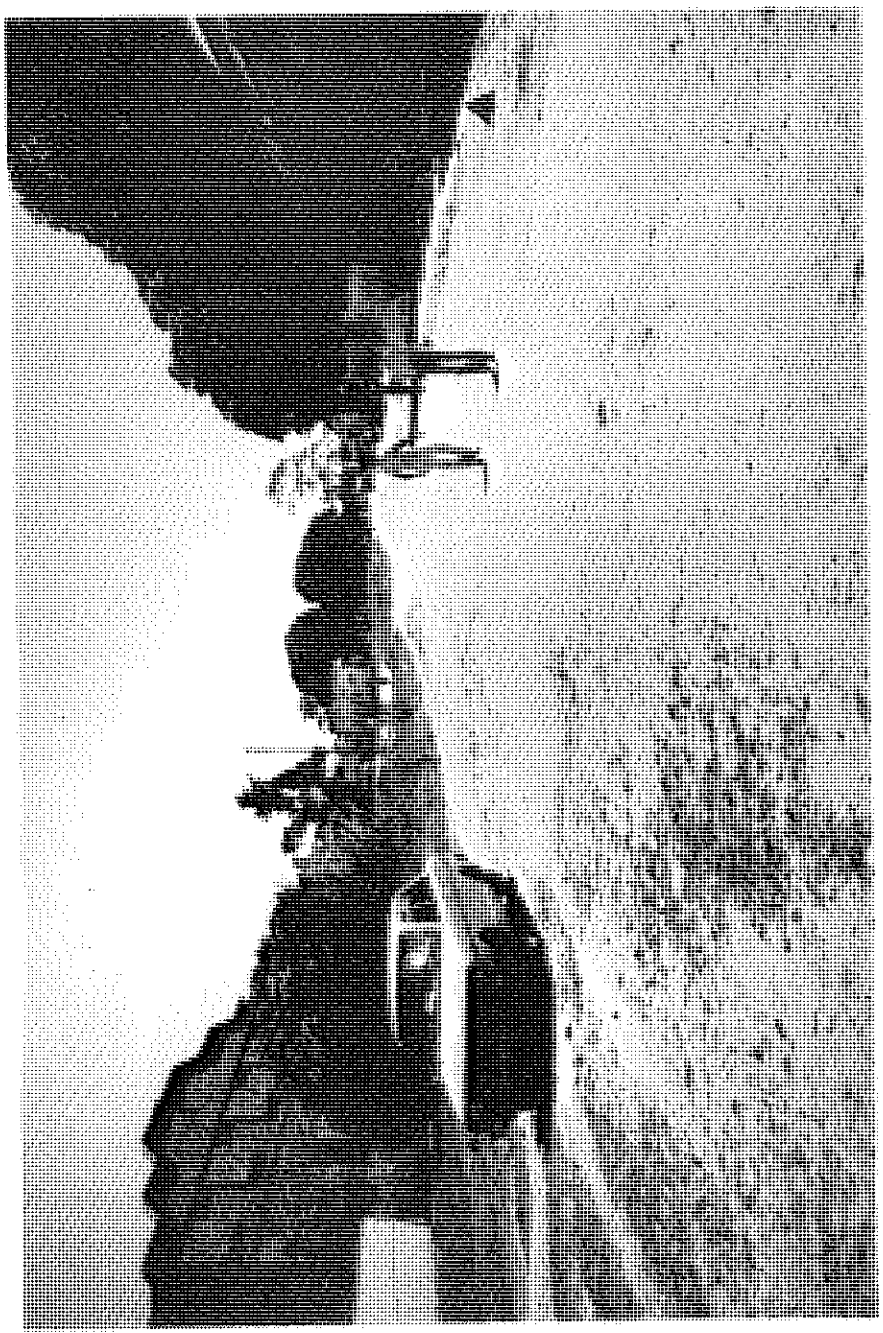
Source: Länderbericht - Sambia.

Both institutions are so new, that it is difficult to judge their impact on the energy situation, but they are manifestations of the growing concern for the energy sector.
Besides these two policy oriented institutions there are other organisations especially parastatal companies with great influence on various parts of the energy sector e.g. Zambia Electricity Supply Cooperation (ZESCO), Maamba Collieries (coal), ZNEL (petroleum procurement). These companies are all subsidiaries of the parastatal holding company Zambia Industrial and Mining Corporation Ltd. (ZIMCO).

3.4. Zambezi district

Zambia is divided into 9 provinces and 57 districts (see fig. 3.4.1), and as mentioned in chapter 2 it was decided to perform the field study in Zambezi district in the Northwestern Province. This province is among the largest and covers about 1/6 of Zambia but the population only represents around 5% of the total (300,000 - 1980 census), so it has an extremely low population density (2 pers. per km^2). With almost no all-weather roads, only 8 % of the population in the province have access to an all-weather road. The low population density and lack of good transportation indicates that the province is among the least developed in Zambia.

Zambezi district is situated in the western corner of the province and from Lusaka, the distance is about 700 km by the shortest route to the township, also called Zambezi. At the last population census in 1980 there were 58,000 people within the district of whom around 8,000 lived in the central township. (To reach this high figure for the township, the census must also have included the surrounding villages.) Only very little statistical information is available about the district, and the uncertainties, e.g. on the census, are large because a number of the villages are situated in locations where transport in any form is almost impossible (see fig. 3.4.2), and there is no all-weather road in the district.



"Main street" - Zambezi township

Geographically the district is divided into two very different parts by the Zambezi river. The river is also the dividing line between two tribes each of which has its own language, culture etc. There is some integration between the two sides but because the only way to cross the river is with a canoe and occasionally a pontoon (small ferry), the process of integration is very difficult. The western part is dominated by grasslands and large areas are flooded every year during the last period of the rainy season. This gives possibilities for growing rice, fruits like pineapples, lemons, oranges etc. especially to the north, while to the south the dominant occupations are cattle raising, fishing, and traditional farming on a very small scale. The soil potential for larger-scale farming seems to be good, but due to the difficult transportation situation, it is a big problem just to get the crops to the local market.

The eastern part of the district consists mainly of woodland and some fairly large state forest areas.

The township of Zambezi is the chief employer on this side of the river mainly because the district administration, the district hospital and the only secondary school are situated here. This also means that the township is a potential market for the large number of small-scale farmers in the district, but usually the farmers are only able to grow crops like cassava, maize and perhaps groundnuts for their own consumption and few have a surplus to sell. This is due to the very low level of productivity in the traditional farming system, where the typical farmer cultivates no more than 2 hectares using family labour and simple hand tools. It is therefore necessary to "import" most foodstuffs from outside the district. Local industry is limited to two carpentry craft shops and three milling companies. There is one parastatal shop, one bakery, about ten mixed shops with food, grocery, clothes etc. and two butchers working on a day-to-day basis, because they have no storage or cooling facilities.

Fig. 3.4.3 shows an outline of the township as seen by ZESCO. Only the houses with a connection to the distribution system are shown and the organised structure indicated on the map is very idealized, e.g. the roads are only small gravel or dirt roads.

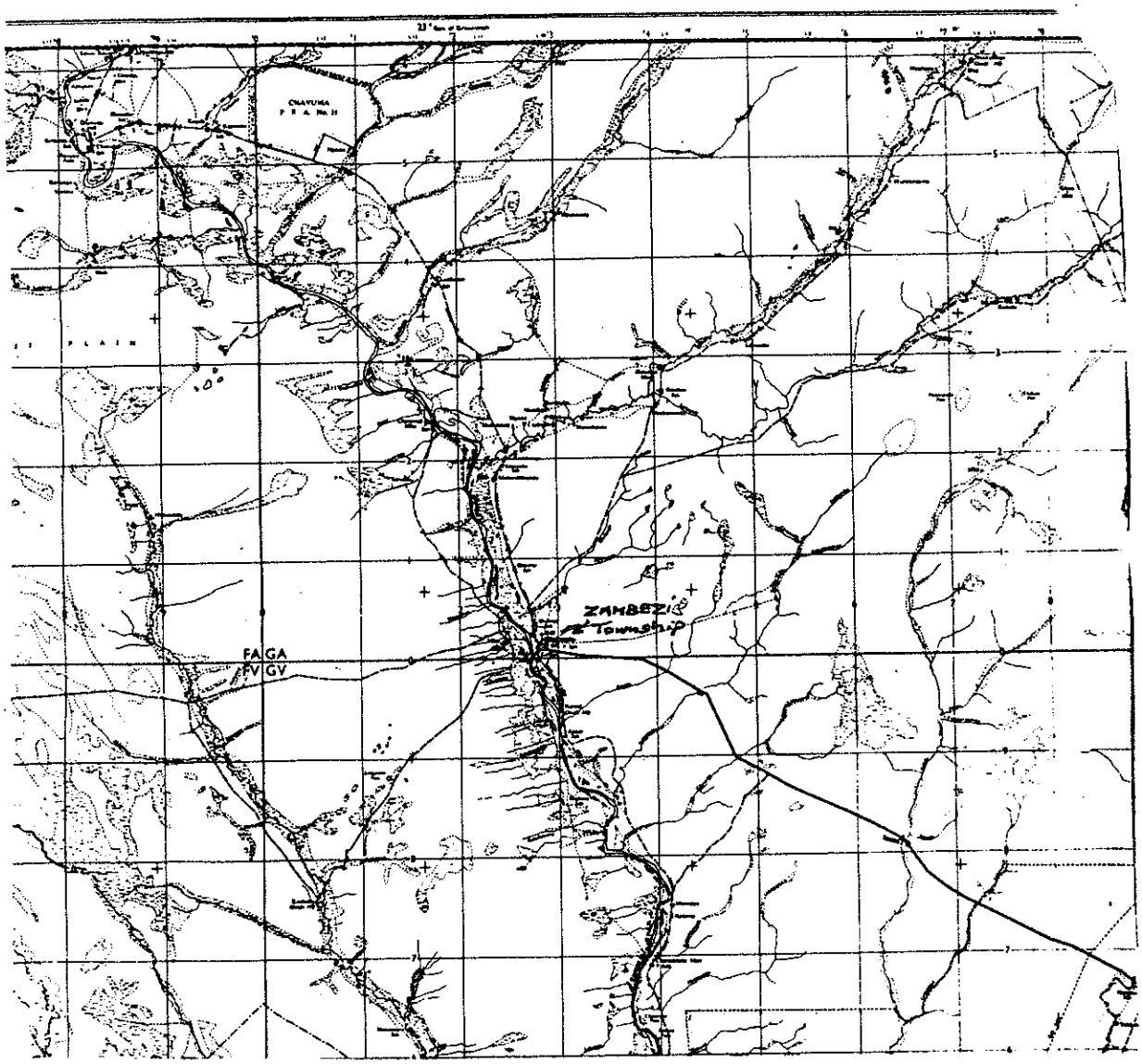


Fig. 3.4.2. Central Part of Zambezi District

Water is supplied through a piped system in the central Zambezi township, and when the electricity supply is stable, the water works and pump station are able to keep a sufficient supply. There is, however, no capacity to extend the piped supply to the surrounding villages. This means that people here get their water directly from the river or from small wells without any possibility of cleaning it. All the other villages in the district are in the same situation. The Department of Water Affairs is trying to secure a better water supply to the villages in collaboration with people employed by the Integrated Rural Development Programme (IRDP) working in the area. Up till now the effort has been met with limited success, because the installed diesel pumps function only short periods, and it is difficult to get the necessary diesel and spare parts. Recently hand pumps have been installed at some of the wells and it seems to be a better solution because of their stability.
In chapter 4.5 the present energy situation in Zambezi is described along with expectations about the future development in the district.

4. WORK PROCEDURE

4.1. General aspects

The fact that the trip was intended to fulfill several different aims meant that it was not possible to set up one specific methodology for the general study. For the more general aspects like strengthening the collaboration with DOE, discussion of methods for project analysis etc. I believe that the best method is to work closely together on a specific project, to be able to take part in the daily routine and try in this way to get acquainted with the persons involved and their line of work. In fact the six weeks in Lusaka were spent at DOE in this way, partly preparing and afterwards following up the field study in Zambezi

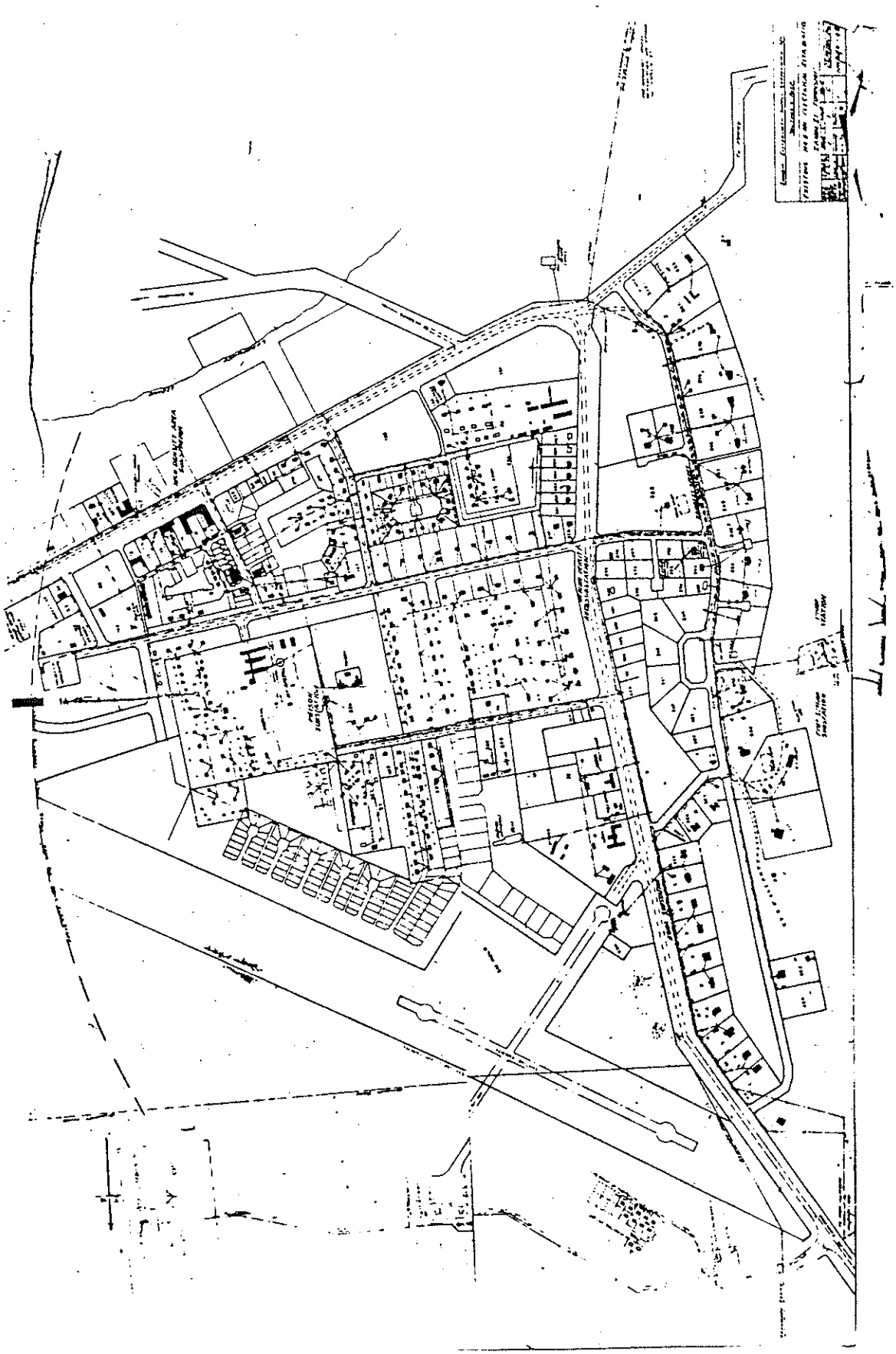


Fig. 3.4.3. Layout of Zambezi Township

and partly taking part in the daily routine studying and discussing the work process and the methods used. I consider the knowledge gained in this way about the work practice in DOE to be of equal importance to the collection of data.

In Appendix A I have made a day-to-day description of the major activities undertaken during the study; therefore, here the emphasis is put on the procedures used for the study of the energy situation in Zambezi.

4.2. Rural energy planning

In the initial phase the traditional energy planning process involves gathering information on

- present energy consumption
- the present energy supply situation
- available local energy resources
- development trends (population growth, expected changes).

When you are looking at a rural area in a developing country, the gathering of the above information can be very difficult. You have to accept the limitations and uncertainties on the available and collected data. In spite of this it is in many ways the easy part of the process, because equally important and far more difficult is the gaining of the necessary understanding of the dynamics of the rural society and the interconnections between social structure, production structure, present energy uses, consequences of changes etc. In a 3-weeks field study it is not possible to get a thorough understanding of the interrelations in the Zambezi society. But hopefully the stay helped to avoid serious misunderstandings, and for everybody involved it was seen only as a first step towards a basis of understanding.

4.3. Data collection - Lusaka

Data collection was started during the preparation phase in Lusaka to give the institutions involved sufficient time to extract and prepare the available data.
Contact was established with:

Zambia Electricity Supply Corporation (ZESCO)
- status and future plans for rural electricity supply,
- tariffs and transmission systems costs,
- details about the local Zambezi production and distribution system.

Meteorological Department
- wind speed,
- solar radiation.

Department for Water Affairs
- hydrological measurements.

Department of Natural Resources
- woodfuel uses,
- conversion processes,
- current research.

Forestry Department
- vegetation types,
- wood areas.

National energy planning data were naturally available from DOE.

4.4. Methodology

Based on reports about previous rural energy surveys, a questionnaire was drafted and discussed. Since the general understanding was considered to be as important as the data collec-

tion and because the total period of three weeks would be insufficient for a statistically representative survey, we decided to base the interviews on a flexible check-scheme and avoid trying to find answers to firmly defined questions. This strategy reduces the possibilities of making statistical comparisons but gives far better possibilities for fruitfull interviews and discussions. Furthermore, one is able to develop one's questioning during the period of study.

4.5. Data collection - Zambezi

4.5.1. Present energy consumption

The collection of data on consumption was mainly based on interviews and, as many electricity consumers only knew the amount paid and not the units consumed, this part of the data collection was supplemented by ZESCO's meter readings.

The consumers were divided into suitable categories, and the following were identified:

Sector	Subsector	End-uses
Household	High income	Cooking/water heating
	Middle/low income	Lighting
	Low income	Ironing
	Subsistence farmers	Refrigeration
		Miscellaneous
Informal industry	Milling companies	Motor drive
	Workshops	Lighting
		Miscellaneous
Tertiary	Schools	Lighting
	Hospital	Cooking/water heating
	Offices	Motor drive
	Shops	

Middle income housing area - Zambezi township

Because of lack of transportation facilities the data collection was limited to Zambezi township and 4 villages (Mize, Chilena, Chingalala, Mushona) within about 5 km from the township. Within this area all the institutions in the tertiary sector and within the informal industry were interviewed. In the rest of the district within these two sectors there are no significant users if any at all. The lack of transportation also meant that it was impossible to visit the small number of commercial farmers located on the northern flood plain.
The household sector was divided into four subsectors. The criterias used were housing quality, load limit of electricity connection, whether or nor the house was electrified and the general information obtained in the interviews e.g. to distinguish between low income and subsistence the criteria was, if the household had any cash wage income at all. In the different subsectors we interviewed:

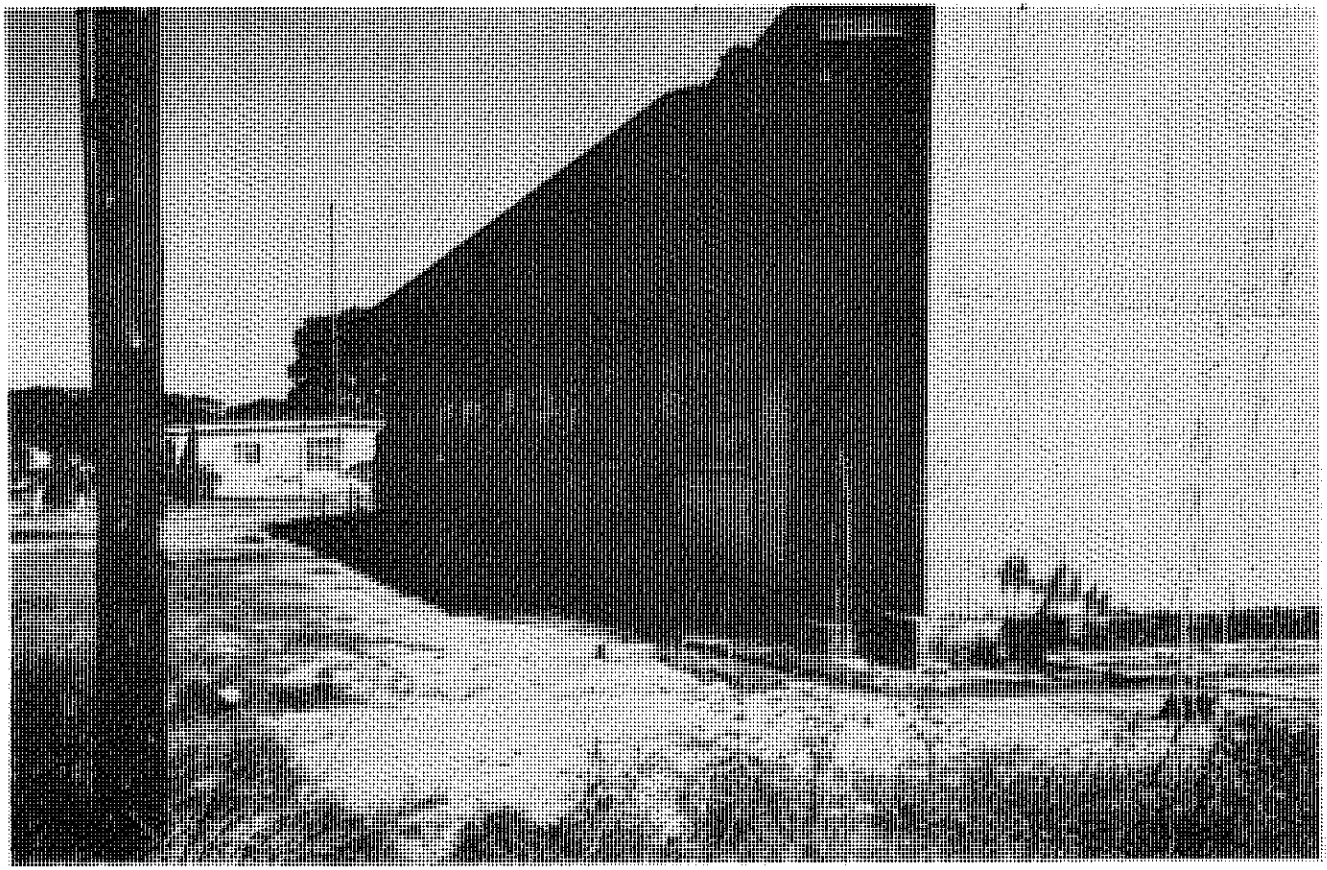
a) high income : 11 households
b) middle/low income : 10 households
c) low income : 16 households
d) subsistence : 17 households

There are no available data about the total number of households in the low income and subsistence subsectors. The total number of high income households is about 70 and the number of middle income is about 250.
It was possible to identify the different end-uses, but especially for the electricity consumers, it was impossible to separate the total consumption into the different end-uses.

4.5.2. The present energy supply situtation

At the end-use level few different fuel types are available (depending on income and end-use type):

1) electricity
2) kerosene
3) fuelwood
4) charcoal.



ZESCO production hall
(exhaustion pipes through the windows)

1. Electricity

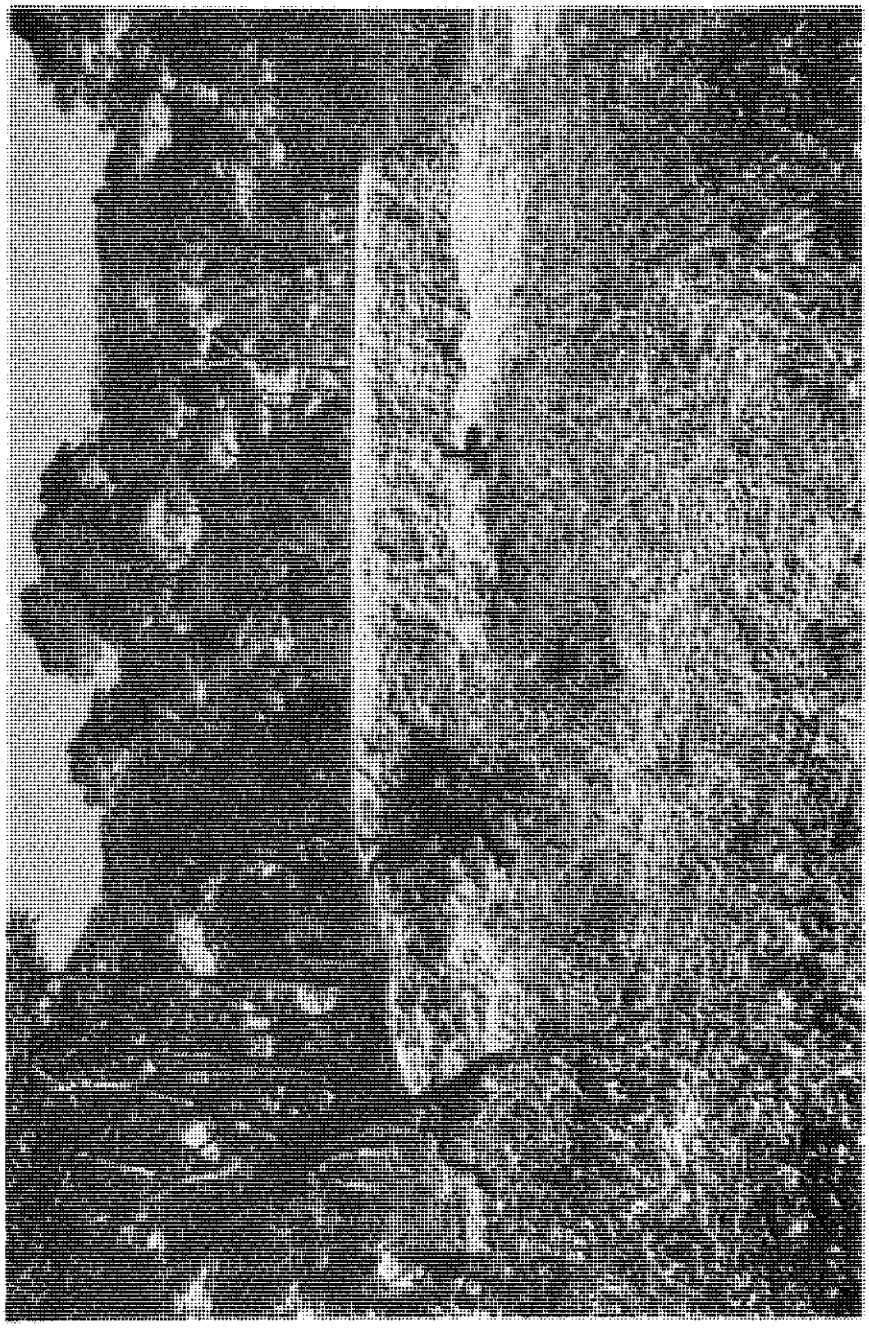
The present electricity supply from ZESCO is based on local production by diesel engines. The local branch of ZESCO assisted by providing us with all the available data on consumption, production, distribution, losses etc. The local distribution system is shown in Figure 3.4.3. ZESCO have their own diesel supply and fairly large storage facilities, and their diesel consumption does not influence the local market. The present consumer tariffs for diesel-supplied areas are shown in Appendix D.

2. Kerosene

Kerosene is brought to the township by the small shops and sold in small quantities mainly 0.7 l bottles since the main use was for lighting in the low income and subsistence households. Kerosene stoves were available but quite expensive, and we did not interview anyone using these stoves.

3. Fuelwood

Fuelwood is the main source of energy among subsistence households and part of the low income households. Even some of the high income groups use fuelwood occasionally, but their source is mainly garden cuttings, while the major part of the other groups collects their fuelwood outside the villages. Average collection time is from 4 to 6 hours and usually the women of the household collect fuelwood twice a week.
The wood is used for cooking and water heating in traditional three stone arrangements.
We had no possibility to weigh the collected wood. Our estimate from volume and weighing in the hand is that one bundle equal to a headload is approximately 25 kg. This is the average collected amount per trip.



Charcoal kiln

The fuelwood is nearly always dead wood collected on the ground and no substantial cutting takes place to provide fuelwood.
There also exists a small informal market for fuelwood, where a headload is sold for k 1, but because the price is fairly high compared with charcoal only very few people buy fuelwood for household purposes.
There are 3 large fuelwood users in the township - the secondary school, hospital and bakery. All three buy their wood, and it is transported on ox-cart from the woodland areas. From what we have observed a large part of this wood consists of fresh cuttings and only a very small part is dead wood.

4. Charcoal

Within Zambezi district there are 145 licensed charcoal burners and most likely also some without license. The licenses are bought at the Forest Department and for a license on a cord (≈ 3 m^3 air dried wood) the price is 35 n. The average number of licensed cords pr month is about 1,000, but this figure also includes e.g. wood for the three mentioned larger wood users and households capable of buying and transporting these large volumes. The charcoal is produced in traditional earth kilns built up where the wood is cut. After the process the charcoal is transported either to the market in the township or to small stands in the nearby villages. The normal means of transportation are bicycles or ox-charts. It is not possible to get any precise figures about the conversion efficiency from wood to charcoal but an expected reduction to 20 - 25% in weight should be realistic with an energy content for the charcoal about twice that of dry wood.
On the market a bag of about 35 kg is sold for k 3.50, but in the villages the usual amount bought was "a bucket" of about 3 - 5 kg at a price of 50 n.

As in the case of firewood, the charcoal is used for cooking and water heating and often also for ironing, if an iron is available. The charcoal stoves (see pictures) are very inefficient due to little contact between the pot and burning coal, and there is a large heat loss through the uninsulated sides.

4.5.3. Available local energy resources

Wood is as noted the dominant fuel and even with the fairly long collection distances, it must be considered the major local resource.

Looking at the district as a whole there will probably be no shortage of wood, but due to the very limited transport facilicilities only a small amount of the resource can be reached, and it is our impression that it is getting more and more difficult to collect the necessary amounts of fuelwood, since some areas around the township and villages are deforested. Whether or not this trend will lead to substitution with other fuels is uncertain. As it can be seen in chapter 5, some of the subsistence households in the villages choose to buy charcoal, when they have a small cash surplus. But they can only afford to cover a small part of their energy needs in this way. It is therefore realistic to expect that the increasing wood collection time will be met by savings instead of substitution, and these savings can not avoid affecting the nutritional standard.

Straw and grass can theoretically be a resource of importance and in the dry season actually large areas are burned to remove the dry straw and grass. The practical possibilities for using the resource are, however, not very good, because it will involve cutting, transporting and briquetting the straw. Even if a successful program can be established to take care of these activities, it will be very difficult to use the briquettes in the existing stoves. In our opinion it will not be realistic to promote projects on briquetting in the near future.

From discussions with the agricultural officer in the district we learned that agricultural residues are not a resource of any importance because farming, although being the most important

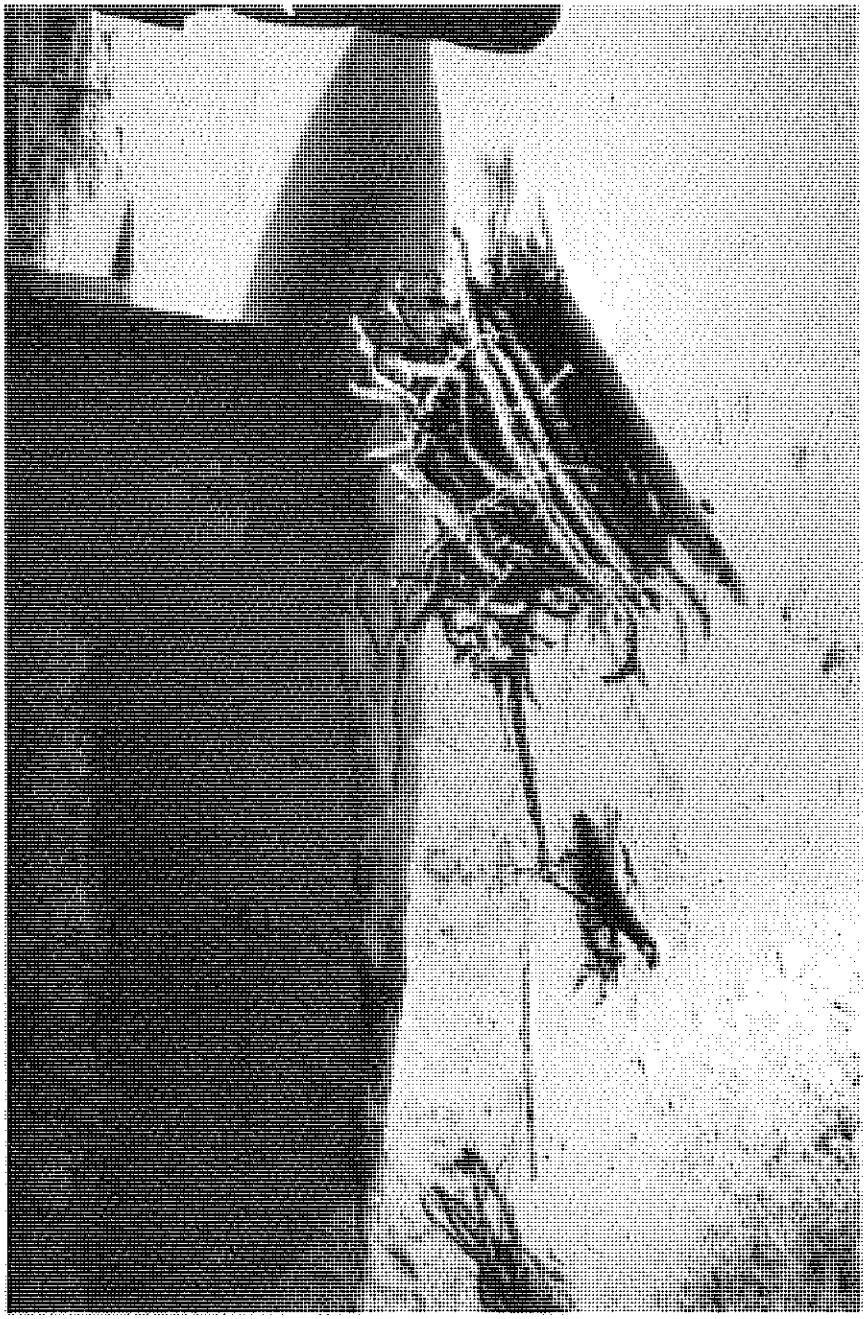
activity in the district, is very small scale. Some of the subsistence farmers may use small amounts of their own maize husks, but it is not very efficient as fuel in the three stone fireplace.

Renewable resources of relevance are solar, wind and hydropower. Through the various contacts in Lusaka we have obtained statistical material on solar radiation and wind speeds. These measurements have been made at the Air Field Station in Zambezi, and the results must be considered as minimum values, since the methods used are fairly simple. The sunshine hours are measured by marks on a paper sheet burned through a burning glass. In partly clouded weather it is difficult to get any permanent record. Wind speed measurements are made with a cup-anemometer, but it is placed between 1.5 m and 2 m above the ground in an area close to buildings and vegetation, and if the figures are to be used to estimate the potential of wind-powered pumps for example, it will be necessary to modify the measuring procedure.

The hydropower potential was estimated in 1981 in a prefeasibility study carried out by a German company paying special attention to the possibilities at Chavuma Falls. We have recent measurements from the gauging station in Chavuma and three other stations. The figures registered are usually only those of mean daily water levels, but the discharge can be estimated. However, it is very difficult to get any precise knowledge about the practical power potential, because it will require more detailed studies at the possible sites to be able to judge the available heights.

4.5.4. Development trends

Besides collecting data on the present situation it is necessary to know as much as possible about the expected development in the district before making any plans for the future. With such a knowledge it will be possible to establish a reference plan that may be used for comparison with any proposed plans.



Bundle of firewood

In the following we will outline the expected development with the already decided changes.

Energy supply

The only major change in the supply situation will be the installation of new diesel engines as replacements for the existing old ones. The major consequences of this change will be a more stable supply and a power capacity surplus, which will allow ZESCO to meet some already announced wishes from United Bus company of Zambia - UBZ - (25 kW), Integrated Rural Development Program - IRDP - (50 kW) and a possible extension of the milling companies (70 kW). The fuel efficiency will improve, and this will reduce ZESCO's present loss on the production, but it will not directly affect the tariffs, and it is not our impression that the consumption will change very much apart from the extensions mentioned.[1)]

The kerosene supply situation is expected to remain stable and no large price variation is foreseen.[2)]
The fuelwood and charcoal supply will be dependent on longer and longer transport distances as deforestation moves further from the villages with time. Whether this situation will lead to changes in the consumption pattern, such as substitution by other fuels, is difficult to foresee. Based on experience from other surveys, however, it is unlikely to occur without external intervention; the most likely action will be to try to reduce the already limited consumption through conservation methods.

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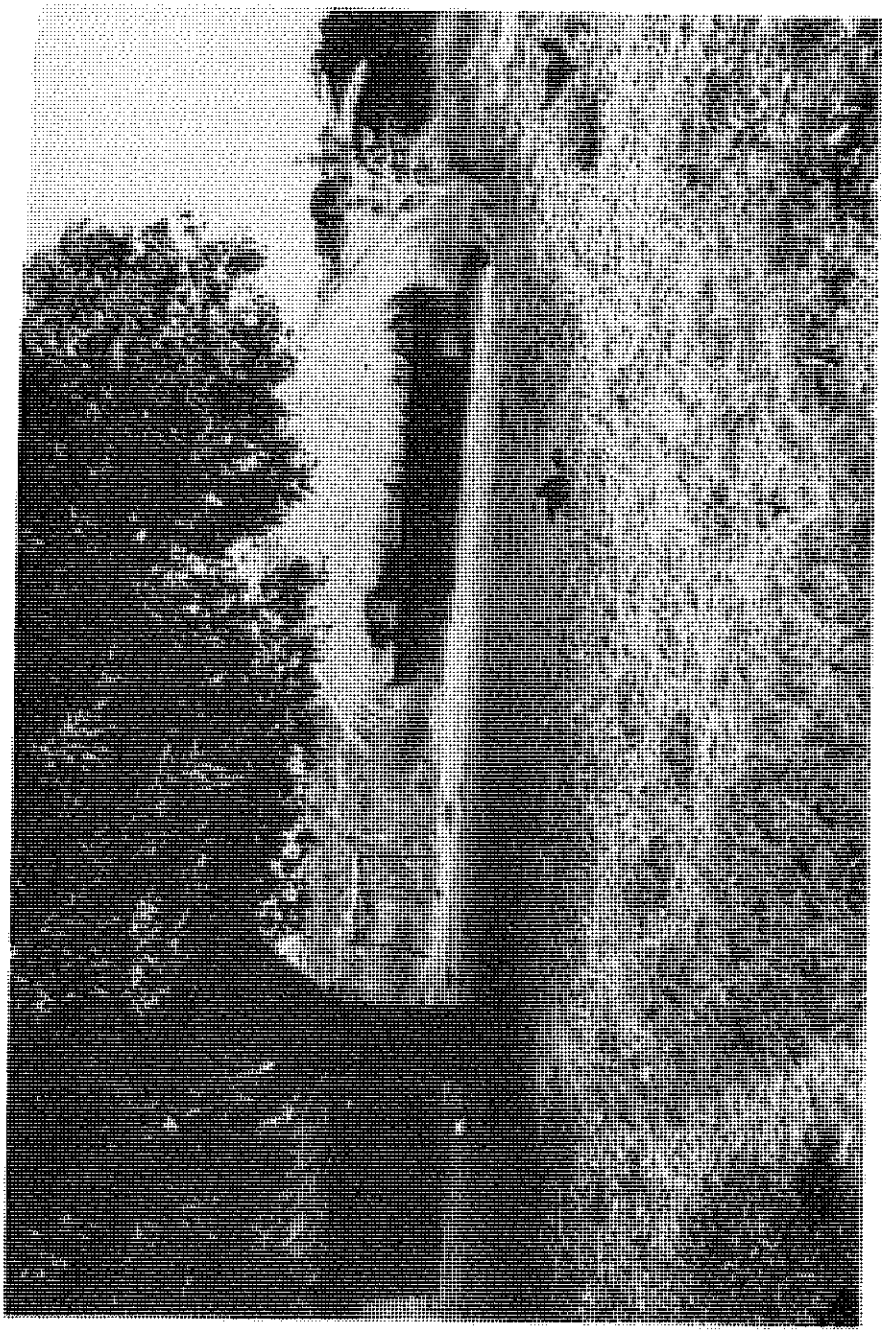
1) Tariffs have been increased by 70% late -85. There are reasons to believe that further increases will come in -86 after a study on marginal tariffs.
This will probably mean that consumption especially in the households will decrease.

2) As one of the results of a new exchange control act in October -85, prices on oil products have doubled within a few weeks.



Village houses and cassava drying

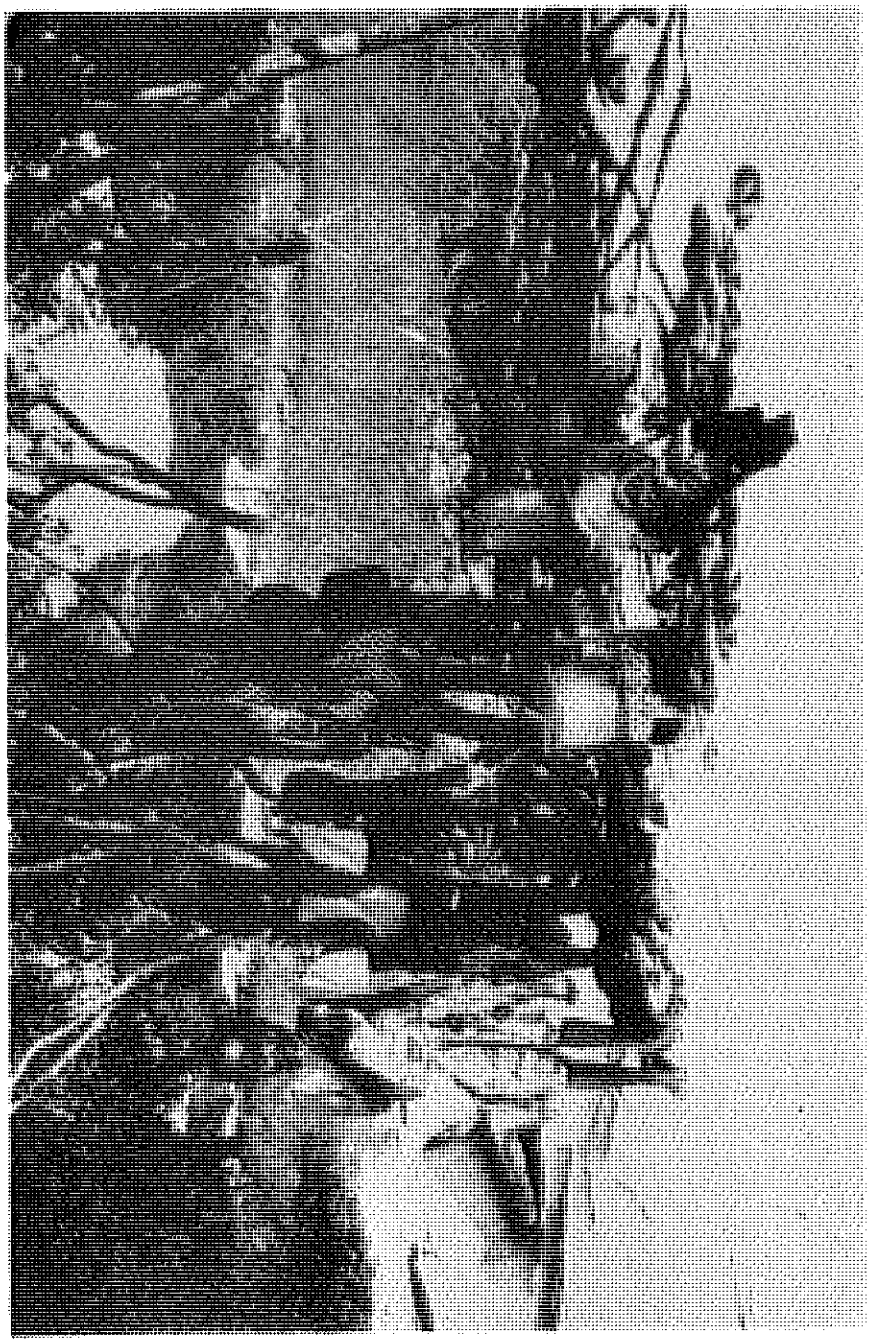
Energy consumption

The only known extraordinary changes in consumption are the mentioned power requests from UBZ, IRDP and the milling companies. There have been plans for a new water supply station, but it has been postponed. Besides these few planned changes the best indicator for the future development is the expected growth rate of the population. Based on material from Central Statistical Office we know that the population in Zambezi district actually diminished slightly from 1970 to 1980; whether this tendency has continued is unknown, but a slight increase of 1 - 2% p.a. is expected because the movement from rural to urban areas is becoming less attractive than in the past, and there are efforts from the Party and its Government to stop this rapid urbanization. A realistic estimate of the change in consumption will therefore be a rise by 1 - 2% p.a., if no extraordinary or externally imposed activities influence the situation in the district.[1)]

Local energy resources

The only expected change in the local resources is the mentioned deforestation affecting the supply of firewood and charcoal. The consequences of this expected development has already been discussed briefly.

1) See note 1, p. 37.



Charcoal stove and three stone fireplace
used at the same time

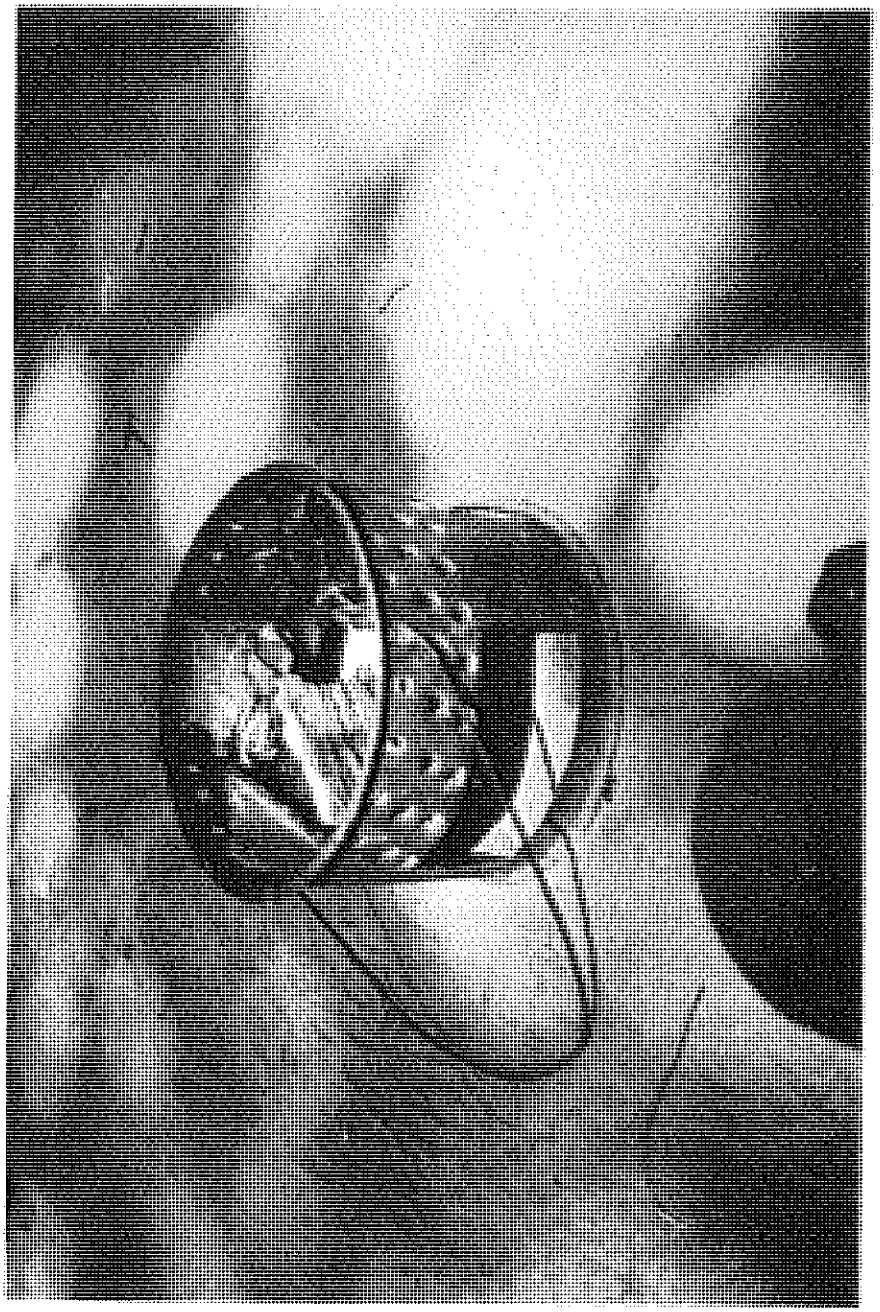
5. RESULTS FROM THE FIELD STUDY

Many different types of information were gathered during the field study in Zambezi to try to understand the local society. Naturally not all of this information is directly related to the energy situation, but we have decided to present only the energy-related data of the study.
The paragraphs in this chapter refer to the corresponding ones in section 4.5.

5.1. Energy consumption data

5.1.1. Household

Based on our interviews and the estimated sizes of a bag of charcoal (35 kg) and a bundle of firewood (25 kg), we have estimated the annual energy consumption for the interviewed households. Due to the quality of the data typical answers were: 2 bundles pr. week or 1 bag a month - the figures are rounded off and some get to resemble each other since e.g. the round number of bags of charcoal covers up the differences. From Tables 5.1.1. - 5.1.4. some trends can be derived; first of all the correlation between "income" and energy source, where the high income households use electricity and charcoal, while the subsistence farmers almost entirely use firewood. Another tendency is that the low income and even a few of the subsistence farmers, especially south of the township, choose to buy charcoal, instead of collecting firewood when they have got cash income. There is no unambiguous explanation to this; the main reason is probably the increasing distances to walk when collecting firewood resulting in less time to work in the field. Other supplementary explanations are easier cooking, low charcoal prices due to regulation, the prestige connected with the use of charcoal etc. It must also be emphasized that charcoal is available in these villages only, because the distance to the



Traditional charcoal stove

township is limited. If it had been possible to visit villages at larger distance from the township, it would probably have shown that fuelwood was the only available energy source. We are surprised about the amount of charcoal consumed in Zambezi; our expectations were that charcoal would not play any significant role since access to the natural forest resources should be easy. But as it is shown in the tables, charcoal is a very important energy source especially within the township.

Table 5.1.1. Annual consumption: High income

Household size	Electricity (kWh)	Charcoal (kg)	Firewood (kg)	Other
2	4800	-	800	75 kg bottle gas
6	2400	840	500	-
5	3600	630	-	-
4	1800	840	500	-
5	3600	550	-	-
9	1500	2100	800	-
7	7200	200	-	-
4	3600	-	250	-
4	3600	840	-	-
5	6000	420	-	-
9	3000	-	800	-

Table 5.1.2. Annual consumption: Middle income

Household size	Electricity (kWh)	Charcoal (kg)	Firewood (kg)
10	840	840	1800
9	600	1470	1725
7	300	840	1300
6	150	-	3600
6	600	840	765
17	845	1260	3840
7	1200	420	2200
6	800	840	-
8	200	1260	2700
5	600	840	385

Table 5.1.3. Annual consumption: Low income

Household size	Kerosene (l)	Charcoal (kg)	Firewood (kg)
9	39	-	4160
3	36	840	-
9	39	450	3360
7	27	-	2600
9	72	840	2300
3	39	840	-
6	39	-	1700
10	39	-	3300
5	20	900	-
11	26	-	5900
7	39	-	3900
6	18	840	700
8	27	840	1535
11	90	2100	-
6	36	1680	-
7	36	840	3000

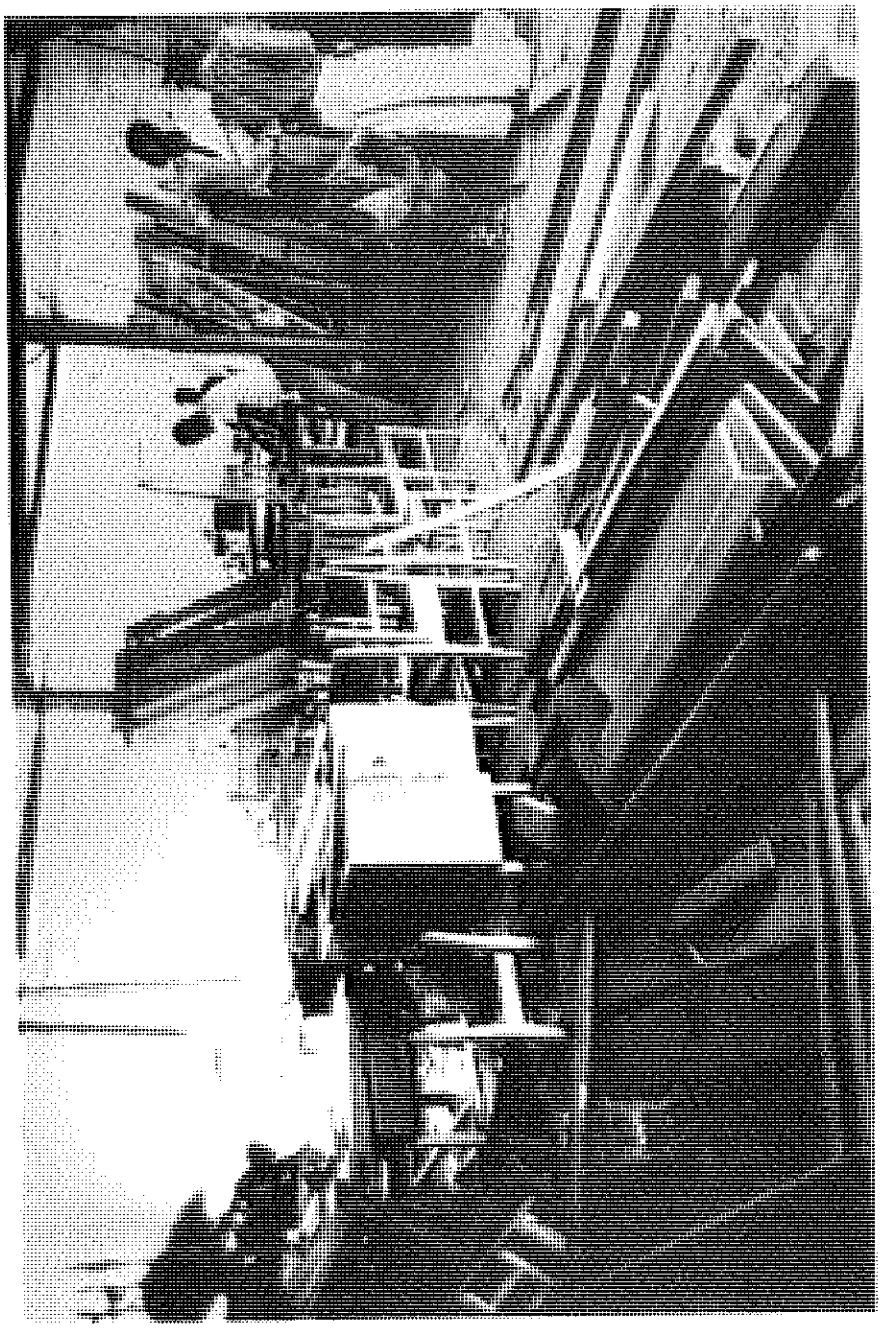
Table 5.1.4. Annual consumption: Subsistence

Household size	Kerosene (l)	Charcoal (kg)	Firewood (kg)
13	9	-	5000
3	3	-	3300
10	9	-	5800
5	39	-	3840
5	9	-	1660
3	26	-	3200
3	20	420	3300
3	20	-	3300
10	78	-	1660
6	39	600	1660
7	39	450	1660
10	39	-	3300
6	9	-	3300
5	18	-	3300
5	39	-	3300
7	9	420	400
4	22	840	-

5.1.2. Informal industry

There are three milling companies and two wood- and metal workshops in Zambezi. Energy consumption patterns are quite alike for the three milling companies, as they have one mill each (rating from 20 to 50 hp) and perhaps a fan and a calculator in the office. The seasonal peak is from November to January, but even in this period there is spare capacity, because it is impossible to buy more maize in the district since, as already mentioned, the majority of farmers produce only for their own consumption and productivity generally is low.

The data obtained during the interviews about electricity consumption are difficult to interprete, because they are based on the size of the bill from ZESCO, and the companies are not in the same tariff categories and furthermore in category D1 (see Appendix D) the price depends on the individual KVA rating. We therefore looked at the accounts at ZESCO to get the actual meter readings.



Wood workshop - RUCOM

Table 5.1.5. Milling companies

			83/84		
Company	Tariff cat.	Installed capacity	Annual consumption (kWh)	Max. monthly (kWh)	Min. monthly (kWh)
LIVANDAH	D 1	50 hp	7,700	1,410	300
NOKENU	D 1	37 hp	25,825	4,880	805
LEMBA	E 4	20 hp	8,700	1,190	325

Table 5.1.5. shows the dominans of Nokenu but even their consumption represents only about 2% of the total electricity consumption in Zambezi. It is difficult to find any confirmation of the general hypothesis that rural electrification initiates rural industrialisation.
Only one of the two workshops - RUCOM - has a commercial consumption of energy ("muscle power" not included) supplied by electricity for a planing and drilling machine, and when metal is available, a welding machine as well. From the accounts we found, that the annual consumption by RUCOM is about 8,500 kWh uniformly distributed over the year.

5.1.3. Tertiary sector

The tertiary sector consists of a fairly large number of incomparable consumers. This presentation will go into depth only with the larger energy consumers.
The Waterworks is the totally dominant electricity consumer in Zambezi with an annual consumption of around 410 to 420,000 kWh which is about 40% of the total consumption. Almost the entire amount is consumed by two pumps at the station, one submersible to bring the water from the river up through the cleaning and filtering system and one to pump it out in the distribution system. Both pumps are normally run continuously from 4 a.m. to 12 p.m. resulting in a very uniform consumption pattern. If the electricity supply falls out, there are two diesel powered pumps on stand-by. Feasibility studies for a new waterworks station have been made, but there are no actual plans for an extension.

Interview with the owner of one
of the small shops

The Secondary School and District Hospital are the two other major energy consumers. It is rather misleading to consider the Secondary School as the actual place of consumption because hardly any of the teaching and administration activities require energy input. However, about 1100 pupils live at the school, and within the campus there are about 90 houses for teachers and workers. About 40 of the houses have electricity installed, and they are supplied from a common transformer without individual meters. Total annual consumption of electricity in the campus area is around 150,000 kWh. Food preparation for the pupils is usually done on large woodstoves and the installed diesel-fueled steam boilers are used only for light meals, because diesel is expensive and the supply is unstable. Diesel consumption can therefore be almost neglected and wood is the dominant fuel. The annual consumption is around 60 tonnes air-dried wood, and it is mainly supplied by various contractors from surrounding villages. They usually cut the wood 5 - 10 km from Zambezi, and bring it to the school in ox-carts.
The stoves are made of bricks and fitted to the large pots being used, this means that the fuel is utilized quite efficiently compared to the traditional household fireplaces. The situation at the District Hospital is somewhat similar although electricity consumption here is directly related to some of the hospital functions like x-ray equipment, autoclaves, laundry and washing machines etc. Cooking is done on firewood stoves like those described at the school and no alternatives are available. Consumption figures are estimated to be around 40,000 kWh and about 30 tonnes of air dried wood. The wood supply arrangements are also similar to those at the Secondary School, and the wood comes almost entirely from felled trees.

The rest of the tertiary sector consists of a number of small energy consumers, their energy consumption mainly being in the form of electricity for lighting, fans, small office machines etc., and some are without any energy consumption at all e.g. the small wholesale shops, the butcher, the primary schools.

We will just mention a few of the energy consumers

Barclays Bank:	10,000	kWh/year	
Resthouse:	7,500	-	
Post office:	7,500	-	
Zango Bakery:	2,500	-	+ 25 T wood
Farmers Training Centre:	2,000	-	+ 10 T wood
ZCBC:	5,000	-	

The wood consumed by the Farmers Training Centre is for cooking food for course participants, and in the bakery the oven is fired with wood. Both have workers hired especially to take care of their wood supply.
Summing up for the tertiary sector it is evident that about 2/3 of the total electricity production is consumed in this sector. Charcoal and paraffin is not used at all. Firewood is the dominant fuel for large-scale cooking, because it is cheap, even here where it is bought commercially, and investments in equipment are low. This wood is like almost all the woodfuel collected or cut in the natural woodland areas, where the natural annual yield is from 0.5 m^3/ha to 1 m^3/ha. This indicates that just these four large wood consumers (Secondary School, Hospital, Bakery, Farmers Training Centre) would have to operate uniformly on 275 ha of woodlands, if their consumption should be met without causing deforestation. This is theoretically not so difficult but in practical life wood is cut as close as possible to the township to avoid the long transportation distances. This means deforestation is growing in "circular" areas around the township accelerated by the use of the same strategy by the charcoal producers.

5.2. Energy supply data

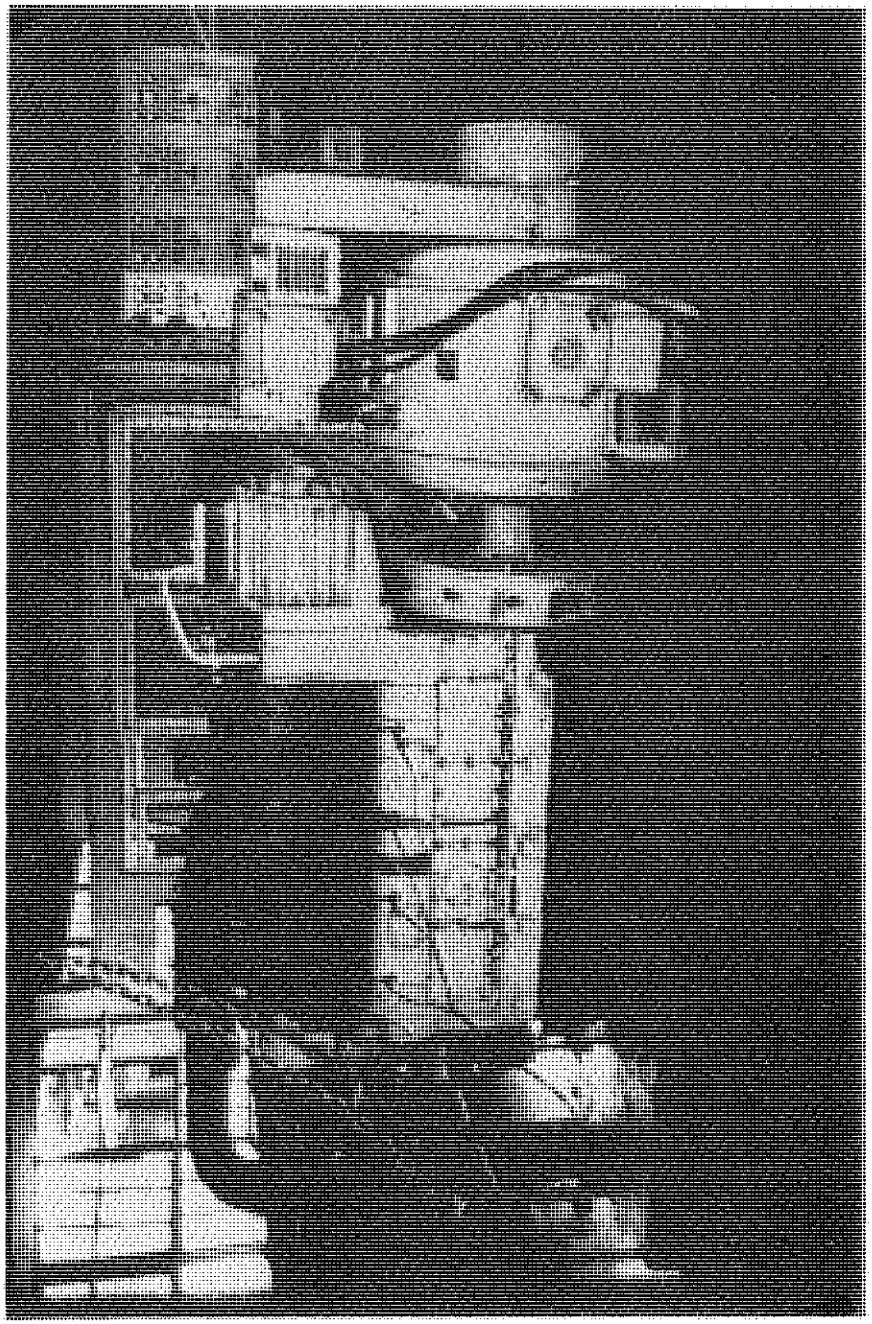
5.2.1. Electricity

As mentioned earlier electricity production in Zambezi is based on diesel engines, and the station was established in 1972 with

four Russian engines with a nominal output of 100 kW each. Three of these engines have been removed and various different engines have been installed as replacement. Presently there are four engines including one of the old Russian ones with a total possible output of 475 kW, but it is not often that all four are able to function at the same time due to general wear and the lack of spare parts. With a present peak demand of around 375 kW it would be very difficult to meet the demands of any new larger consumers.

New diesel generators are being supplied and installed under a Danish loan and will be operating by mid-1986; this should raise the capacity to 750 kW and give a more stable supply.

The condition of the present engines means that the main task for the ZESCO-branch in Zambezi is to keep the system running and be not so much concerned with engine efficiency, maintenance costs etc. Some data was obtained in Zambezi and from the regional headquarters in Ndola about the numbers of consumers, units consumed, revenue and costs. These figures are shown in Tables 5.2.1 - 5.2.3 and a supplementary figure of interest is the distribution efficiency which is found to be from 85 - 95% depending on consumption level. For model simulation purposes we also collected production data for one year from log-sheets (half hour registrations of production output). The efficiency of the diesel motors and generators can be derived from the data and is found to be from 0.40 to 0.48 l diesel per kWh produced. For comparison the new diesels are expected to have an efficiency around 0.28 to 0.30 l/kWh, so the savings will be around 30 - 40% of the present consumption. Since the revenue presently only covers about 20% of the total costs, these saving will be positive for ZESCO, but the costs are still expected to be more than double the revenue. Tariffs are fixed on a national basis so the main benefit for the electricity consumers in Zambezi from the new diesels will be a more reliable supply. The distribution system (shown in Fig. 3.4.2) is well built and will be sufficient for the foreseeable future.

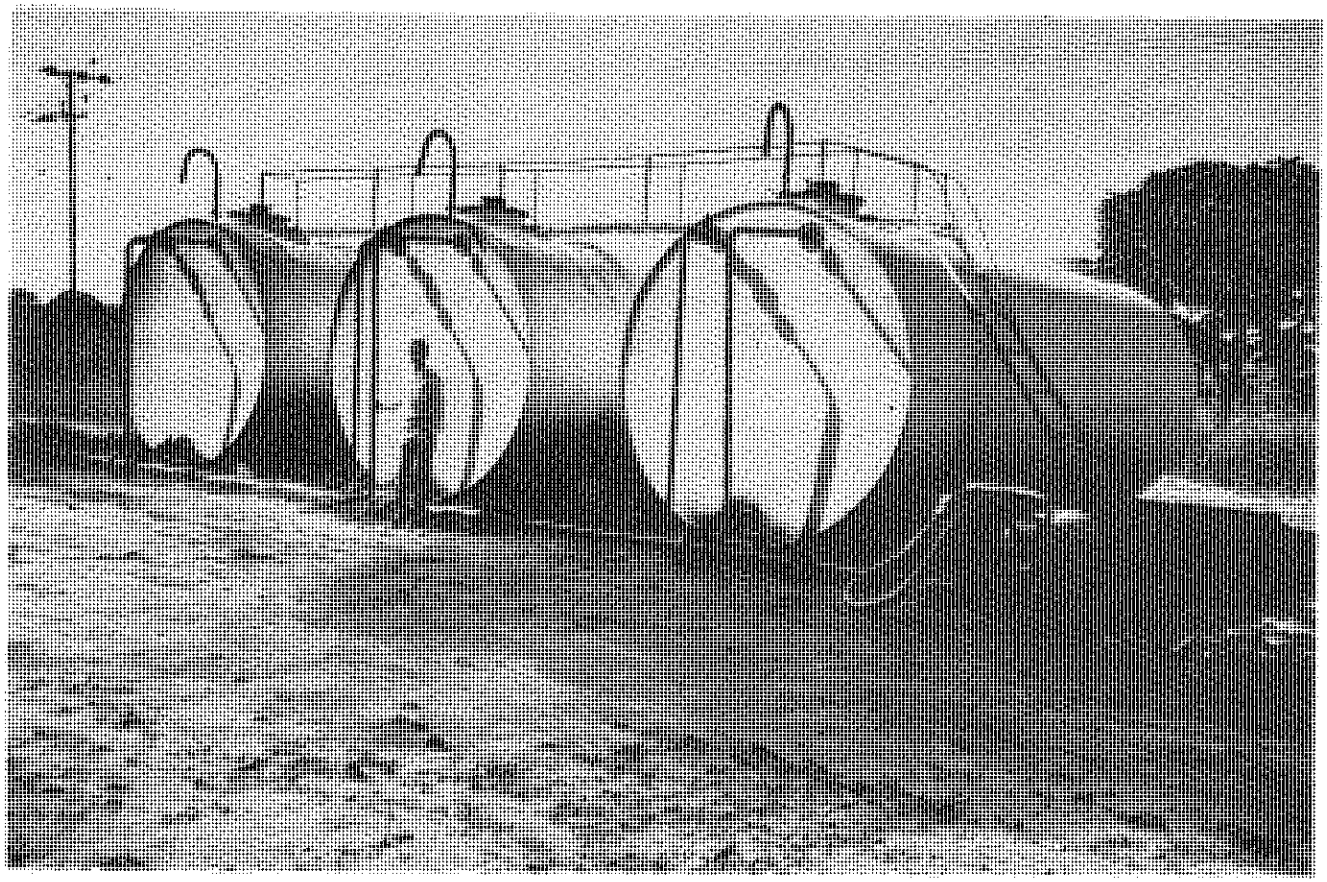


The last Russian diesel engine

Table 5.2.1. Zambezi district - Electricity consumption

Tariff/year		1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
E1	a:				63	108	104	98	90	83	84	91
	b:				21345	36620	43419	38245	31546	33523	30399	30283
	c:				655	1066	1264	1225	1190	1194	1124	1416
E2	a:				56	102	130	126	139	151	150	171
	b:				84639	88185	102248	107567	119506	148469	146862	145578
	c:				6336	5890	6931	10758	13602	13303	13161	17472
E3	a:				31	34	38	61	54	54	52	53
	b:				100971	100866	130620	164025	167386	186702	176875	198123
	c:				6336	5890	6931	10758	13602	13303	13161	17472
E4	a:				19	28	26	28	24	26	29	34
	b:				121405	121519	145188	134723	132194	111379	99845	109533
	c:				9578	9453	11511	14025	16645	16730	16473	20972
D1	a:				4	4	4	4	4	6	6	5
	b:				596788	631858	699326	723115	701701	746241	635963	622019
	c:				21069	27008	35248	45086	51968	56468	52399	62009
S1	a:								14		15	14
	b:								59089		55169	48970
	c:								472		441	395
Peak demand (kW)					255	263	295	318	312	340	372	

where: a = number of consumers
b = units consumed in kWh
c = revenue collected in Kwacha



Diesel storage tanks - ZESCO

Table 5.2.2. No. of consumers in Zambezi 83/84

		E1	E2	E3	E4	D1	S1	Total	kWh consumed
April	1983	85	152	55	29	6	15	342	89,020
May	"	86	152	52	30	6	16	342	89,134
June	"	86	146	53	29	6	16	336	93,388
July	"	88	150	52	29	6	16	341	89,849
August	"	87	151	54	29	6	16	343	95,078
September	"	89	153	53	28	6	16	345	114,831
October	"	87	159	54	28	6	15	349	99,629
November	"	88	159	53	29	6	15	350	108,199
December	"	91	167	54	32	6	15	365	88,830
January	1984	89	170	54	33	6	14	366	91,043
February	"	90	167	54	34	5	14	364	103,253
March	"	91	171	53	34	5	14	368	92,354
								Total	1,154,608

No. of consumers in Zambezi 84/85

		E1	E2	E3	E4	D1	S1	Total	kWh consumed
April	1984	90	172	56	34	5	14	371	94,797
May	"	93	171	58	34	5	14	375	90,858
June	"	89	170	58	34	5	14	370	108,988
July	"	89	172	57	34	5	14	371	106,493
August	"	91	177	58	34	5	14	379	120,435
September	"	92	174	59	34	5	14	378	107,637
October	"	92	179	57	34	5	14	381	107,253
November	"	93	180	56	33	5	15	382	110,701
December	"	90	185	58	34	5	15	387	96,533
January	1985	89	186	58	34	5	15	387	100,537
February	"	89	186	57	35	5	15	387	89,553
March	"	88	182	57	35	5	15	382	90,206
								Total	1,223,991

Table 5.2.3. Annual production costs - Zambezi

Year	Diesel Consumption (litres)	Diesel costs (Kwacha) (a)	Operational costs (Kwacha) (b)	Total costs (Kwacha)
1978/79	519,875	148,471	112,561	261,032
1979/80	526,540	150,374	145,017	295,391
1980/81	523,200	198,428	140,012	338,440
1981/82	539,402	348,388	195,312	543,700
1982/83	450,928	294,947	188,492	483,439
1983/84	482,979	359,553	213,813	573,366

(a) Diesel is bought at wholesale price inclusive of sales tax.

(b) Operational costs include
- wages and salaries of the staff
- general maintenance/repair
- local transport (8% of wages and maintenance fixed)
- administrative charges (20% fixed).

N.B.: The total volume of the diesel storage tanks is
3 x 45,000 litres

5.2.2. Kerosene

As described in chapter 5.1.1 the only present use of kerosene is for lighting purposes in poor households. If the price of paraffin remains more or less constant, no changes in this pattern can be expected. If charcoal prices rise more rapidly, the use of kerosene stoves may increase for the middle income households. The stability of the supply to Zambezi is, however, not too high due to the long transport distance, bad roads and the small amounts consumed.

Table 5.2.4. Forest vegetation type - an analysis by district

Zambezi

Vegetation type	* Area (1000 ha)	% of W.A.	% of L.A.
4	220	21.4	12.0
6	23	2.2	1.3
9	1.0	1.0	0.6
10	3	0.3	0.2
11	22	2.1	1.2
13	749	72.7	40.8
16	3	0.3	0.2
Total Wooded Area	1030	100	56.2
17	804		43.8
18			
Total Land Area	1834		100

Vegetation type: see Appendix E

Notes: WA: Wooded Area
LA: Land Area
* : Totals may not add up due to rounding

5.2.3. Fuelwood

The collection of fuelwood both for households and the larger consumers takes place almost entirely in the natural forest/ woodland areas. State forests and plantations contribute to the energy supply only when wood from the thinnings can't be sold as building material. In Table 5.2.4 the total land area of Zambezi district has been analyzed, the vegetation types identified and the covered areas of each type estimated (explanations of the vegetation types are in Appendix E). It is evident that the district is dominated by woodland, grasslands and the state

Women collecting firewood

forest areas. Even if the percentage of woodland is low compared to the average in Zambia, the annual yield from the woodland areas could easily meet the present and near future demand for fuelwood without causing any deforestation, if it was possible to have easy access to the resources. However, as already mentioned this is not possible due to the short manageable collection distances for the households and uneven distribution of the woodland areas. For example the west bank side is mainly grasslands with few wooded areas, while the eastern and northern parts are dominated by woodlands and the state forests.
Forest Department is responsible only for managing the state forests and maintaining some control over the woodlands through licensing, but replanting in the woodland areas is not a part of their responsibility. The population is encouraged to plant trees but since it is a very long term "investment", and wood traditionally is a free commodity, the incentive to plant is very low, and actually very little is being done.
The utilization of fuelwood in the households' open three-stone fires is from a strict energy point of view likely to be about 10 %, but besides cooking the fire also provides such conveniences as light, heat in the cold season, insect protection and so forth, so it is difficult to discuss efficiency in this context. Furthermore, there are presently no realistic alternatives for the low income and subsistence population. Finally, it is worth stressing that the main causes of the initial deforestation must be found in charcoal burning, the large wood consumers' cuttings, other wood uses like building material, and the slash and burn farming tradition rather than the households' collection of mainly dead wood.

5.2.4. Charcoal

Charcoal is produced 8 - 10 km outside the township, and the burners move with the resource, as the earth kilns are built where the trees are felled. After about a week the first part of the kiln is finished, and the charcoal is dug out and placed into bags and transported to the market in Zambezi township or the small stands in Chilena and Mushona village (for prices,

One cord wood for charcoal burning

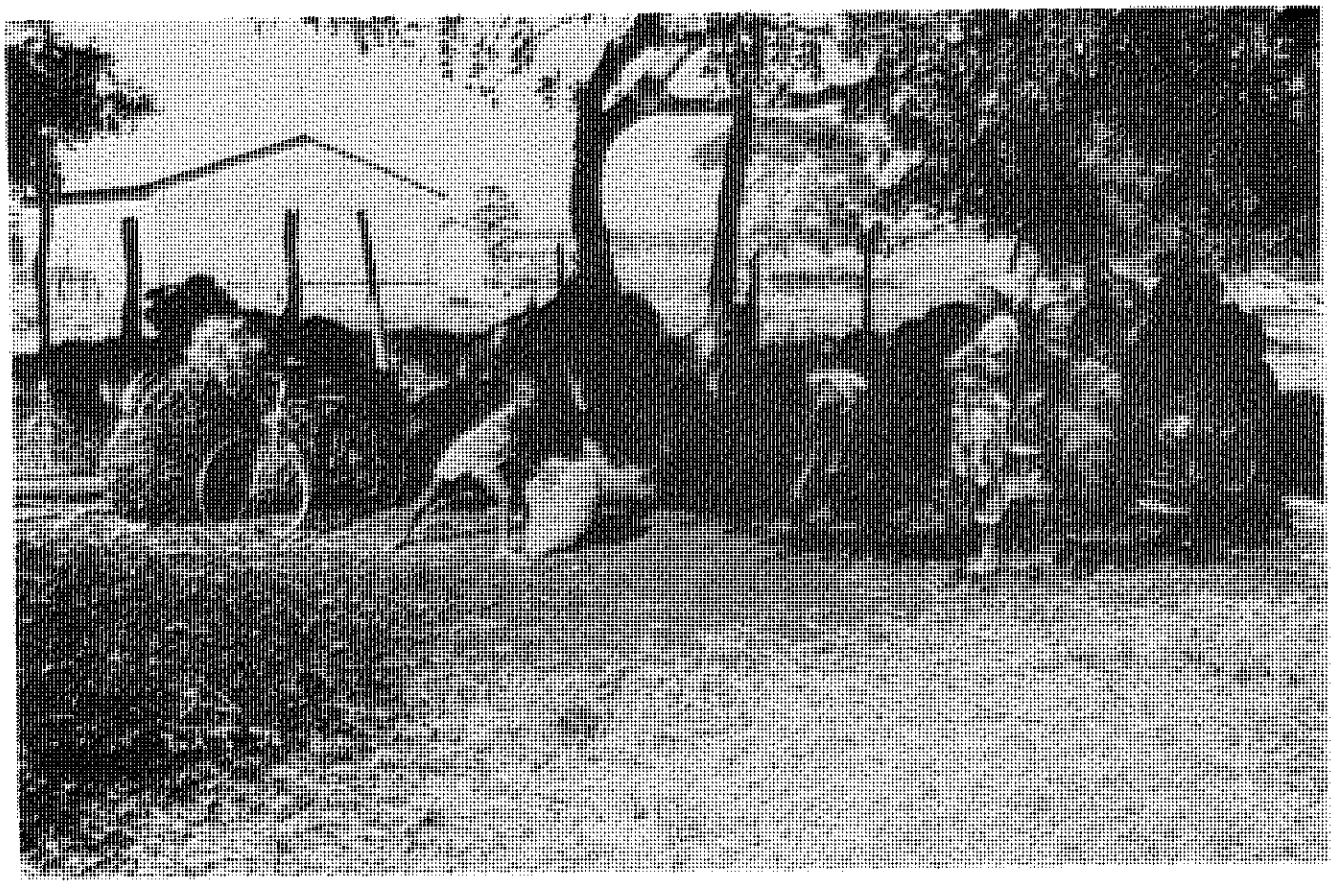
weight etc. see chapter 4.4.2). Charcoal burning is not allowed on the west bank side of the river, because this area would easily be deforestated, and the consequences could be very serious on the sandy soil. As already mentioned charcoal is used mainly for cooking in the traditional Zambian charcoal stove. The energy efficiency of the stove is not expected to be more than 20% and combined with the conversion efficiency in the kilns, which is probably not more than 25%, the overall energy utilization from charcoal is about 5% compared with around 10% for the open fire. Together with the fact that charcoal is produced from felled trees, this indicates that as an energy source charcoal is a much greater strain on wood resources than fuelwood. The need for savings is therefore also greater, and it is possible to make more efficient stoves and kilns, but these new technologies are still at the research stage, and are unlikely to be implemented in Zambezi for some time.

5.3. Local energy resources

The dominant resource wood has already been discussed thoroughly, and it was impossible to get any data on the other biomass resources like straw, dung and agricultural residues, so we will just present the data collected on wind speeds, solar radiation and some of the data on hydro potential. As described in section 4.4.3 we visited the places where background data were registered (Air Field, gauging station), but the statistical data were obtained through the head offices in Lusaka.

In Table 5.3.1 the available data from Zambezi about solar radiation and windspeed is shown along with other meteorological data of more indirect interest (For conversion purposes 1 langley = 11.624 Wh/m^2 and 1 knot = 0.515 m/s.)

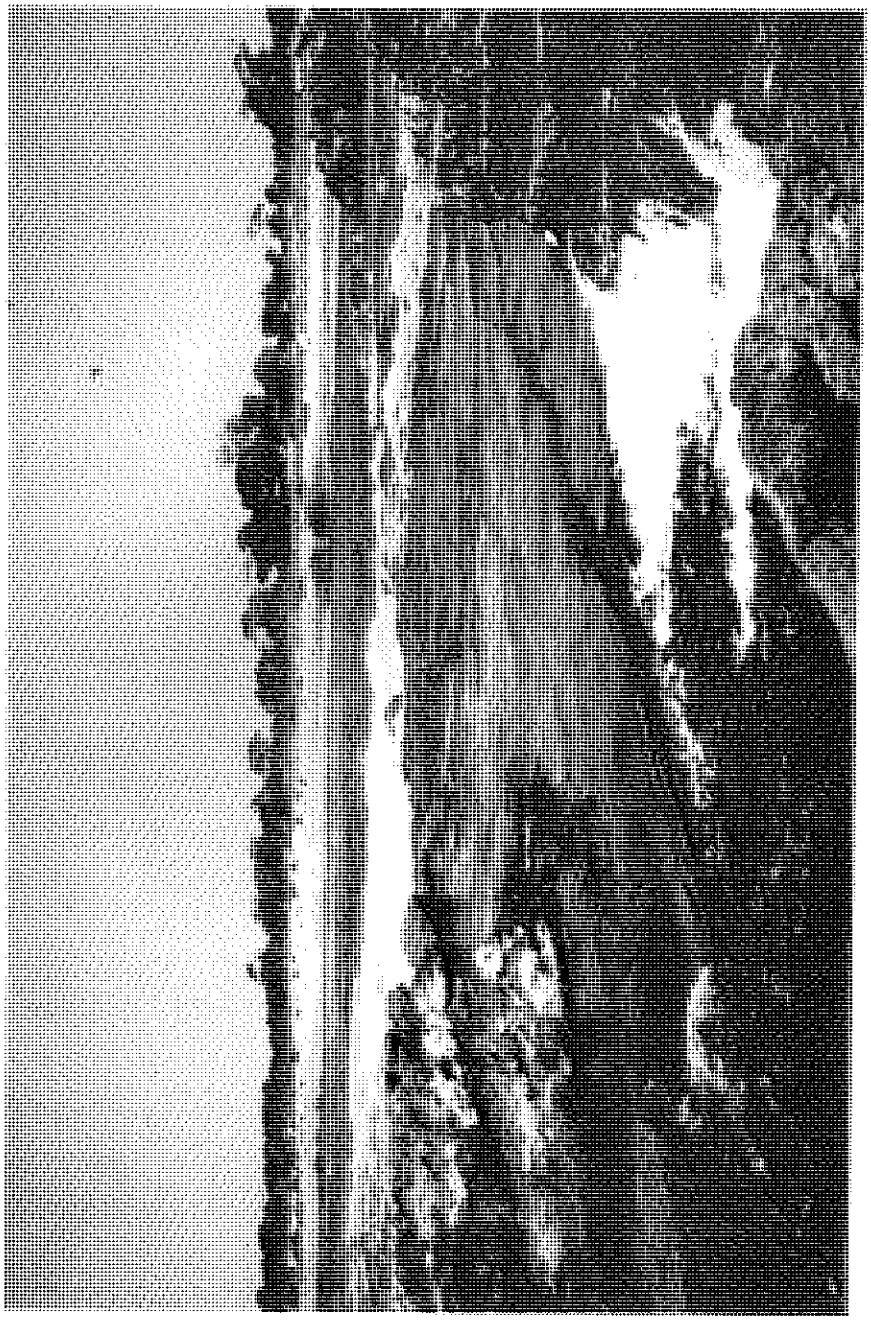
The direct sunshine potential is high with about 2800 sunshine hours pr. year and an average global radiation of more than 0.23 kW/m^2, while the windspeeds seem to be too low for utilisation by wind turbines. Because windspeeds are measured at 1.5 to 2 m above the ground, it is necessary to try to estimate the windspeeds at around 10 m to get an idea about the relevant wind



Charcoal market in Zambezi township

Table 5.3.1. Meteorological data from Zambezi

Months	Mean pressure (mb) (0800 hours)	Mean temperature (^{o}C)	Mean max temperature (^{o}C)	ABS max temperature (^{o}C)	Mean min temperature (^{o}C)	ABS min temperature (^{o}C)	Mean sunshine hours/day	Global solar radiation (langleys/day)	Mean windspeed (knots)	Mean monthly evaporation (mm)	Mean monthly rainfall (mm)	Rain days 0.3 mm	Rain days 1 mm	Rain days 10 mm	Frost days
No. of years available	17	27	27	27	27	27	22	-	21	17	30	30	30	30	24
July	898.4	17.2	26.8	31.8	7.1	0.0	9.8	447	3.3	164	Ø	Ø	0	0	1
August	896.8	20.0	29.6	36.0	10.2	1.4	9.7	483	3.8	214	Ø	Ø	Ø	0	Ø
September	895.1	23.9	33.0	37.7	14.5	3.7	9.2	508	3.8	258	6	2	Ø	0	0
October	894.4	24.7	33.0	38.1	16.6	9.1	8.1	494	2.9	241	41	8	5	1	0
November	894.5	23.1	29.8	36.4	17.4	11.3	6.1	428	2.4	180	152	17	14	5	0
December	893.6	22.5	28.3	33.9	17.6	12.4	5.6	408	2.3	152	212	20	17	7	0
January	893.3	22.5	28.3	34.0	17.6	12.1	5.4	402	2.2	155	219	20	17	7	0
February	893.0	22.3	28.0	33.0	17.6	12.3	5.4	402	2.1	151	208	19	16	7	0
March	893.9	22.4	28.6	33.6	17.3	12.1	6.0	409	2.3	154	170	16	14	5	0
April	895.1	22.1	29.3	32.9	15.4	7.5	8.1	448	2.6	167	38	5	4	1	0
May	896.8	19.5	28.4	33.2	11.1	2.4	9.5	451	2.8	159	4	Ø	Ø	Ø	Ø
June	898.2	16.9	26.5	31.1	7.6	-2.2	9.6	430	2.9	147	Ø	Ø	Ø	Ø	2
Year	895.3	21.4	29.1	38.1	14.2	-2.2	7.7	443	2.8	2142	1042	107	87	33	3



Chavuma Falls

potential. To do this it is necessary to have more precise information about measuring conditions, theoretical wind distribution etc. Since this is not possible here, we have chosen to "guess" a realistic figure based on experiences from other studies, and it seems to be reasonable with a multiplication factor between 1.5 and 2. Even with this correction the average wind speed does not exceed 3 m/s, and this is fairly low even for water pumping, but it is a possibility especially since wind speeds are highest in the dry period, there are considerable variations day and night, and it would not be difficult to find better sites than the measuring station. Hydropower is also of interest, but to be able to evaluate the actual potential, it is necessary to have much more detailed studies (discharge, available height, possibilities for intake or dam, etc.). The available statistical data are mean daily water levels at a number of gauging stations in the district. The positions of the stations are shown in Fig. 5.3.2, and it must be emphasized that the sites originally have been chosen without considering the hydropower aspect. As an illustration of data quality and the large seasonal variations Appendix F shows data sheets for station 1 - 150 Zambezi Pump House and 1 - 105 Chavuma Falls.

The potential at Chavuma Falls was examined by a German consultant for ZESCO in 1981, and a layout of their proposal for a power station at Chavuma is shown in Fig. 5.3.3.

The site has a large power potential, but because of the long distance to Zambezi (about 85 km) it might be too expensive a solution compared to the use of diesel engines or making a connection to the central grid, but further studies are necessary before any decision can be taken.

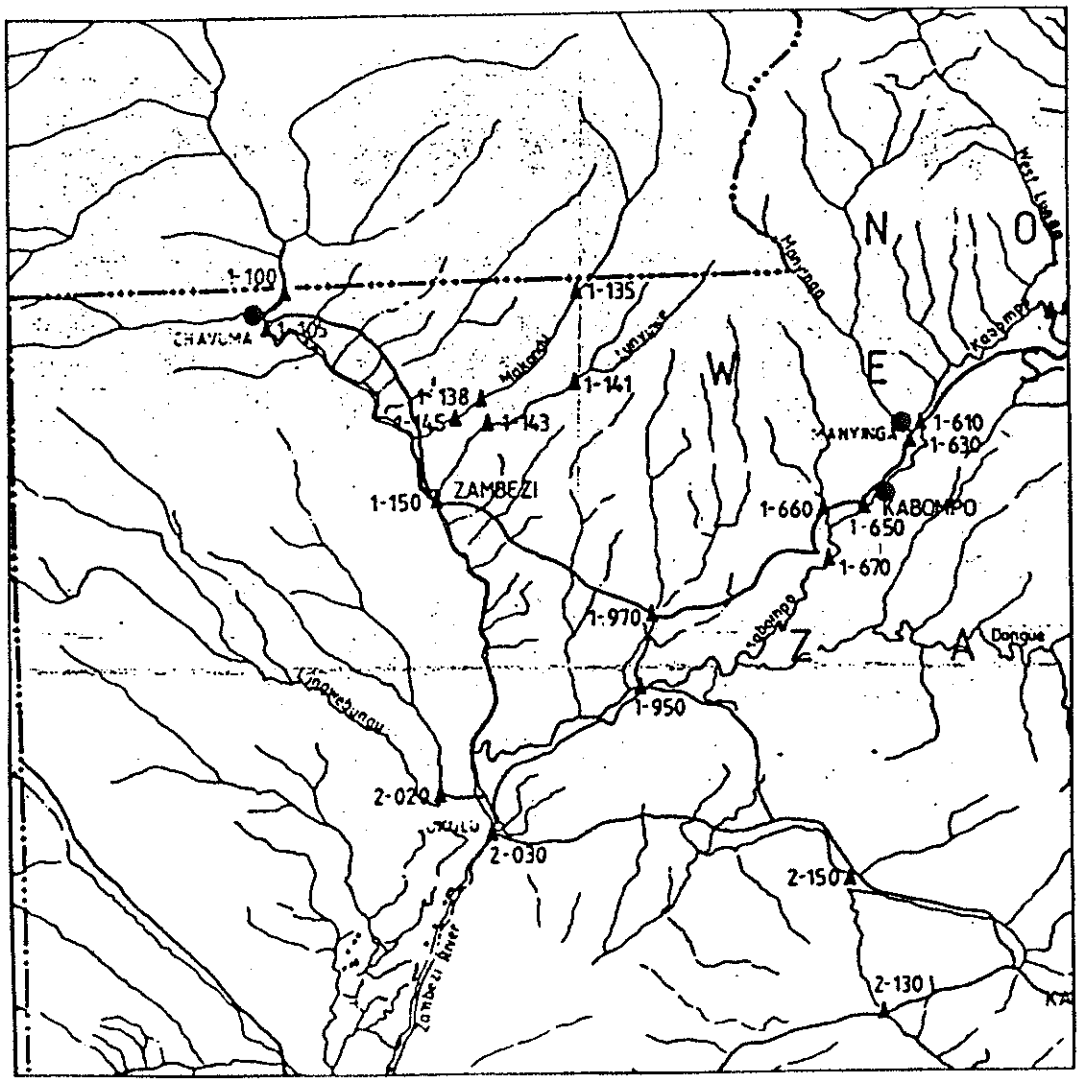


Figure 5.3.2. Gauging stations

Source: DECON

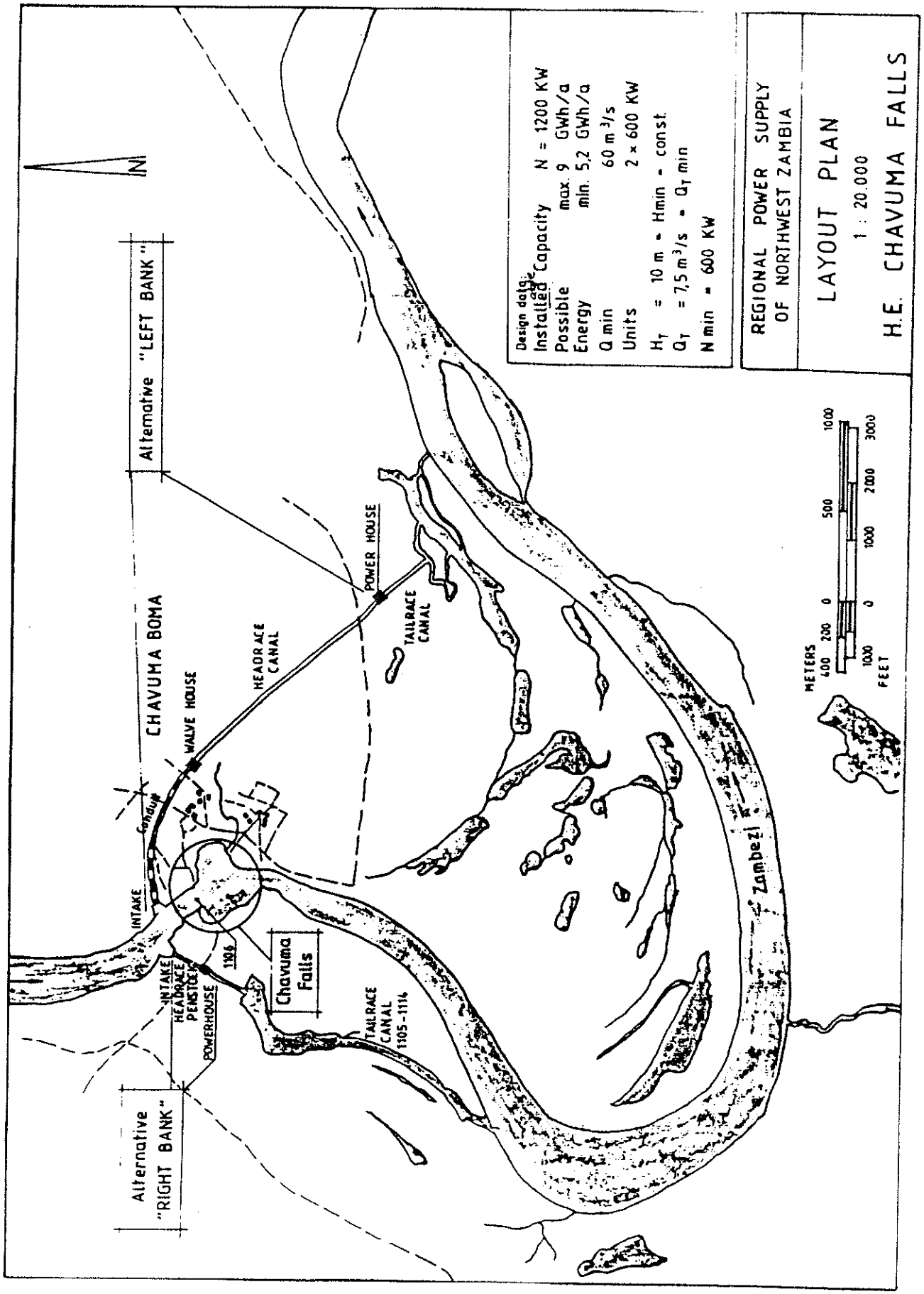


Fig. 5.3.3. Proposal for layout plan. Source: DECON

Interviewing women in a village

6. CRITICAL REVIEW OF THE STUDY

6.1. General experiences

In the introduction several related purposes of the study were mentioned. Looking back at the results and experiences gained, the general impression is that nearly all the expectations drawn up have been met. Naturally the insight into rural society that can be obtained in a period of three weeks is very limited, but these limitations were well known, so the expectations were kept low. It is compared with these expectations that the study is considered successful. This report is concentrated around the collected data, the methodology used and a small critical review is presented in the following, also focusing on these aspects of the study.

6.2. National data

The introduction to Zambia and its energy sector is mainly statistical and based on generally available sources. Since the purpose of the introduction is to present a general framework for the district study especially to people with little or no knowledge about Zambia, only very few comments or interpretations of the data have been added. It must therefore be emphasized that it is only a very general introduction, and it does not pretend to give an adequate picture of the country. As is the case in many other developing countries, a general problem in Zambia is the data collection for statistical purposes, especially about activities in the rural areas. Furthermore, the large rural subsistence economy does not fit into the present statistical frameworks, which have been established in developed countries.

6.3. Methodological weaknesses

Several points of criticism can be raised when reviewing the general methodology for the survey. Two aspects will be emphasized here; first the inability to register variations through time. Because the survey is performed only during one visit, it is necessary to predict variations through time, both seasonal and annual.

The data on electricity production and consumption and also solar and wind data are available for several years so the problem is not relevant here, but it is certainly relevant for all the data about fuelwood and charcoal. These fuels are almost entirely used by the poorer households together with three large wood users in the tertiary sector. The variations in consumption of the three large users are fairly well known, e.g. the Secondary School holidays, home leave periods for the pupils etc., but smaller variations are not registered. It is more difficult to estimate the variations in the householders consumption. If we look at electrified high income households, it is evident that their seasonal variations are small, but whether this trend is transferable to the wood users is unknown. Due to the mild climate heating is relevant only in a very short period, but what impact the seasonal variation in available crops has on fuelwood for cooking can be determined only through a more in-depth study.

The second aspect is also especially related to household consumption and concerns the problem of accuracy, when data are based on memory recall. The reason for basing the interviews on recall instead of on measurements is that through recall each item of data takes much less time to collect. The drawback is often that we receive less accurate answers and even misunderstandings leading to wrong data. From the interviews among electricity consumers, which we were able to cross-check with ZESCO, it was obvious especially in the tertiary sector, that people exaggerated their consumption in order to present their business as more important than it really was. However, this tendency didn't appear in the households, but the general problem of accuracy was present. Because the data are not used in an aggregated form, but mainly as indicators for the consump-

tion pattern in rural areas, the inaccuracies are not too critical.

6.4. Survey data discussion

The results of the household interviews must be treated with special care, when the data are analyzed. As mentioned earlier there are problems regarding the estimation of the weight of bags and bundles, but even if these estimates are reliable as average values, the listed data contain uncertainties from interpretations of questions and answers. We will just give a few examples:

Family size. When asking about the family size, it is difficult to be sure whether the figure is going to be for the actual consumption unit or perhaps include family members who work and eat part time somewhere else, since the term family size may include these persons from the villagers' point of view.
If the figure is going to be used for per capita consumption calculations, it would be necessary to know more about the family composition e.g. number, age and sex of the children, as the food and thereby energy consumption naturally are not the same for small children and adults.

Collection frequency. By asking about the number of bundles used a week and how often the family collects wood, it was expected that figures would match, or possible inconsistencies could be explained. This was also generally true, but in several cases it was impossible to match the figures. The explanation could be that the number of people collecting together varied or one family was helping another, but in a few cases it was impossible to find any explanation at all, so it was necessary to accept that a family used 3 bundles a week and collected only two!

Extraordinary uses. Because the answers are based on memory recall, attention is usually focused on recent events forgetting

the long time trends. As an example: in a couple of families where data indicated a high kerosene consumption it turned out that it was caused by the recent illness of a child, and the parents had been sitting up several nights. In a similar way, the brewing of beer could affect the wood consumption data.

6.5. Interpretation of results

It has been mentioned several times in this report, that we see deforestation as a problem in its early stages in Zambezi. This hypothesis is not based on specific measured data but on various indicators such as statements from households about increasing collection time and distance, the high level of charcoal consumption, the fact that there is a market for wood, prices paid by the large wood consumers etc. The indicators must be treated with great caution, because there might be other explanations than deforestation to almost all the individual indicators e.g. the collection distance might depend on where the family has its fields, and the collection time could include other activities.
However, all the indicators together supplemented by our own impression from the survey form quite a strong background for the hypothesis, and it is also broadly accepted by the local branch of the Forestry Department.

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APPENDIX A

Description of activities undertaken during the trip to Zambia.

The field study in Zambia was integrated in the Department of Energy's activity program. Silvester Hibajene took part in all the activities in Zambezi, the external meetings in Lusaka and the discussions of methods and results.
Gordon Mackenzie participated in the two meetings in Zambezi and Peter Søndergård participated in the last meeting.

For the stay in Lusaka at DoE only the external and the major internal/DOE activities are listed.

APRIL

22 : Introduction to the staff in the Department of Energy (DOE).
Meeting with the involved staff members - Peter Søndergård, Gorden Mackenzie, Michel Lagoutte and Silvester Hibajene - presentation of the project status and DOE's activities in rural energy planning.

23 : Timetable and list of activities for the preparation phase were drawn up.
Visit to Central Statistical Office obtaining the available data on socio-economic indicators, housing and population etc.

24 : Meeting with chief engineer R. Nyberg and ass. planning engineer A.Mwakoi, Engineering Services Division, ZESCO about possible assistance to obtain data about the local electricity production and consumption in Zambezi.

25 : Meeting at Department of Water Affairs, Hydrological section with Chileshe about the available hydrological data (water level, discharge) from Zambezi district. The gauging stations of interest were pointed out. Meeting at Meteorological Department with chief meteorologist Mwangala about available data on solar radiation and wind speeds.

26 : Meeting at the Danish Embassy with the Chargé d'Affaires Thomas Schjerbeck presenting the project and discussing the status of the Danish loan for new diesels to Zambezi and 3 other townships in N.-W. province and the possibilities of an evaluation in, e.g., 1987 of the impact of the new diesels on the local society.
Letter to ZESCO presenting the detailed demand for data.

29-30 : Getting the necessary maps at Map Sales. Examination of data from a National Energy Survey (based on questionnaires) performed in 1984 by UNZA, DOE and NEC but yet unanalyzed. The "rural-questionnaire" was studied along with the responses to be able to judge the relevance of questionnaires in a rural energy survey.

MAY

1 : National holiday.

2-3 : Preparation of check lists for the various types of interviews planned.
Discussion of different methodologies for the survey.
Arrange practicalities about transportation, water, food etc.

6 : Lusaka to Zambezi.
Practical accommodation arrangements were made with Jørgen Bjarnesen - doctor at Zambezi District Hospital and Jens Buttenschön - IRDP building officer in Zambezi.

Introduction meeting

7 : Meetings with
- local police to present the participants and get permission to take photographs
- District Executive Secretary A. Masenga and Development Secretary Chilunga to check up on the letter from DOE and possible arrangements.

Introduction meeting was arranged.

8 : Visit to ZESCO's local office and meeting with Technician in Charge A. Mwanza and presentation of introduction letter from ZESCO-headquarters (Appendix B). Mr. Mwanza provided us with a desk in his office as working place during our stay.
The technical installations (storage tanks, diesel engines, switch-boards, transformers and distribution network) were examined, and mr. Mwanza described the present situation and the essential facts about the station.
Log-sheets for the last 2-3 years were examined and due to the amount of information, we decided to select a sample of

- a work day (Wednesday)
- a Saturday
- a Sunday

from either 2nd or 3rd week every month in the period April 1983 till April 1984. This amount of data should be sufficient for the simulation activity (the log-sheet were taken to Lusaka, copied and returned when we were picked up).

9 : Meeting with selected representatives from the district administration, ZESCO, milling companies, charcoal burners association and district hospital.
The meeting was used to present the Department of Energy, the present energy situation, the main purposes for the visit to Zambezi and our wishes about local cooperation.

Using Mwanza's knowledge about the district, we made a timetable for the rest of the study. The timetable was typed and distributed to the persons we wanted to visit.

10 : Meeting with the Senior Administrative Officer Nsofwa about assistance from the administration.
It was most important that an interpreter be placed at our disposal for the whole period. The interpreter was competent in both the local languages (Lunda and Luvale) and English, and apart from that his knowledge of the local community was invaluable.

Meeting with the Agricultural Officicer Namuswa about local farming conditions, the IRDP-LIMA programme, agricultural residues for energy purposes etc.

11 : Interviews in high-cost housing area. We visited 13 households. (ZESCO tariff group 3 plus a few group 2)

12 : Sunday.

13 : Interview with some of the larger consumers
- LEMBA Milling Company
- Nokenu Milling Company
- Livandah Milling Company
- Zango Bakery and Shop

14 : Interview with all the small shops (10-15 depending on what is considered a shop) and Rucom Industries, a wood and metal workshop.
We would have liked to interview the owner of the filling station, but he was absent.
We visited the District Hospital and were shown round by the Administrator Sibulo, whom we also interviewed.

15 : Visit to the village Mize on the west side of the river.
Courtesy visit to the Paramount Chief Ndungu to introduce ourselves and talk about the present energy situation.

One of the chief's counsellors showed us around in the nearby villages, and we talked to a few of the villagers but made no real interviews.

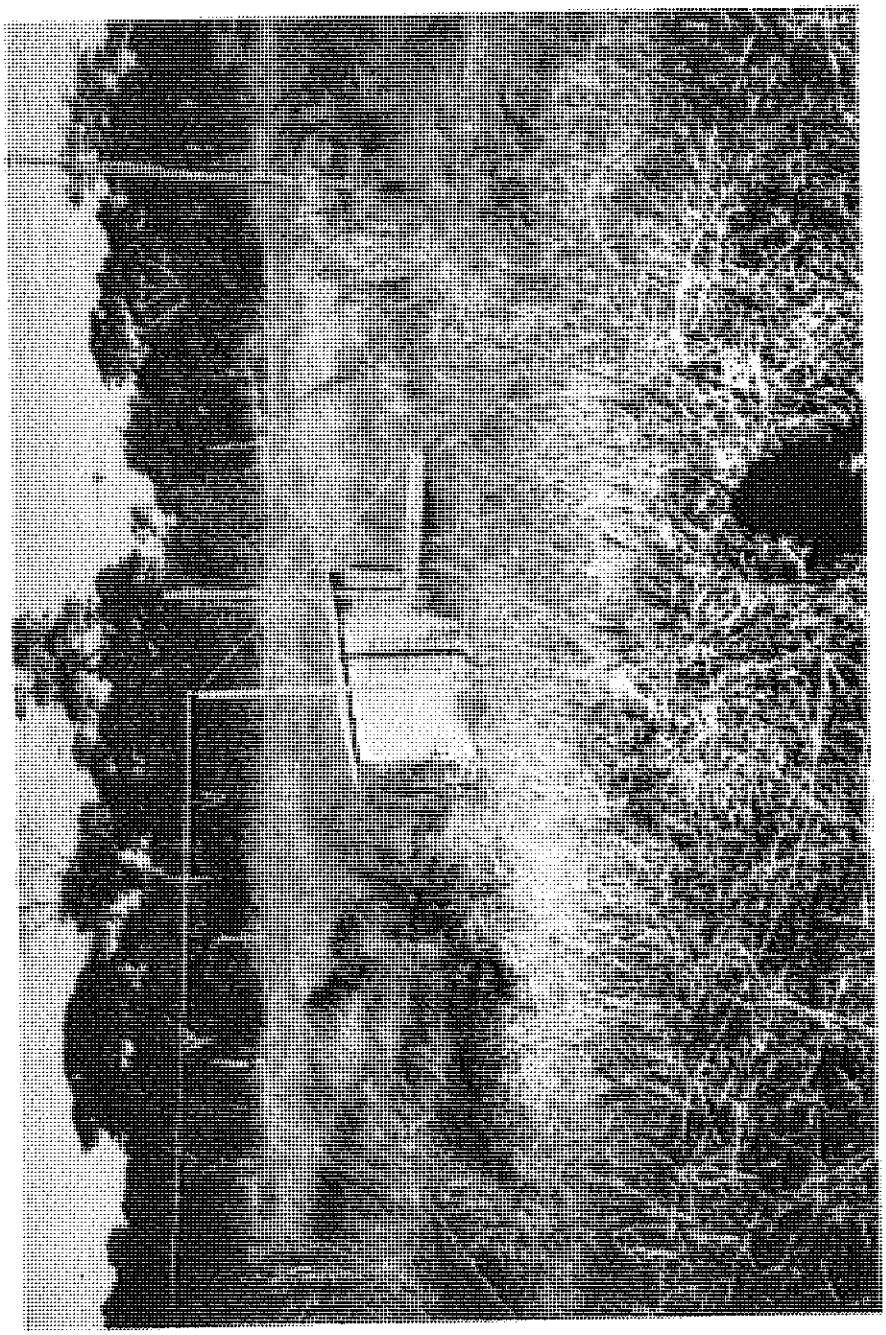
16 : Visit to Water Works in Zambezi.
The water supply is pumped from the river and cleaned before it is pumped out in the piped distribution system in the central parts of the township.
Supply is fairly stable from 04^{00} till 24^{00} and the water works are by far the largest consumer of electricity from ZESCO.

Visit to the local air field.
There are no more regular flights, but the field is still fully staffed; besides the few planes actually arriving, their main tasks are radio control and simple meteorological measurements.
We interviewed the technician in charge and the meteorologist.

17 : Visit to Farmers Training Center (FTC).
FTC conducts courses for local farmers from the district in agriculture, cattle keeping and various related subjects. 20 to 30 courses with an average of 20 participants a year. The participants stay at FTC during the course, and furthermore 22 families (teachers, administrative officers, IRDP employees) live permanently within the center area.
Visit to Chilena village.
Interview with 8 families within the village area.

18 : Interview in the middle and low-cost area in the township.
We talked with 16 households.
(Tariff groups E 1 and E 2 and some not connected to the electricity distribution system.)

19 : Visit to Chinyingi Mission about 25 km north of Zambezi



Small hydropower station - Chinyingi

township. Some of the fathers have constructed a micro hydro plant. The plant was not in function but was being repaired.

20 : Meeting at Department of Water Affairs with mr. Ndeke, the main subjects were rural water supply, pumping possibilities (diesel pumps, hand pumps or wind mills). Hydrological registration is limited to registration of water levels at the water works.

Visit to Chingalala village/compound.
Interview with 10 households.

21 : Visit to Zambezi Secondary School.
Interview with the deputy head master.
The school has about 1200 pupils of which 1100 are boarding.
Most teachers and administrative officers have houses within the school area, in all 93.

Visit to Mushona Village.
Interview with 10 households and an informal meeting with the ward chairman (local party representative).

22 : Meeting at the Forestry Department with senior officer Musumali about the development in wood resources both within the state forest areas and in the natural forests.

23 : Visit to a charcoal-burning area and examination of the local type of earth kiln.
Preparation of the last meeting and a preliminary analysis of the findings.

24 : Meeting with the same representatives as at the initial meeting. Unfortunately, some of the participants were out of town, but after a short presentation of the results of our interviews, we had a good discussion about possible actions.

25 : Visit to Chavuma Falls to get an impression of the possibilities for a local mini-hydropower station.

26 : Return to Lusaka.

27 : Holiday.

28 : Presentation in DOE of some of the experiences and results gained during the study.

29-31 : Preliminary report writing mainly concentrated around the activities.

JUNE

1-2 : Weekend.

3 : Discussion of UNDP/WB status report for Zambia.

4-5 : Rounding up and completing the data collection.

6 : Department meeting concerning
- the UNDP report and DOE's comments
- our field trip.
Various other subjects.

7-10 : Holiday.

11-12 : Statistical work on the consumption data.

13 : Discussion of SADCC co-operation in the energy sector and possibilities for projects.

14 : Visit to YWCA in Lusaka to see an exhibition about appropriate technology including woodstoves, solar grain driers, small water pumps and so forth.

15-16 : Weekend.

17 : ZESCO statistical information received, analyzed and some small additional requirements were discussed.

18 : Examination of the total project cycle with the Danish diesel as a good and well documented example.

Meeting with Chief Conservator of Natural Resources Mr. Chidumayo in Natural Resources Department about the work he has been doing during the last 5-6 years on wood-use for energy purposes.

19 : Revisit to ZESCO, Water Affairs and Meteorology to gather the last information.

20 : Meeting in DOE with discussions of the project development and possible interesting new dimensions that should be included.

21 : Visit to University of Zambia - School of Engineering where we had a meeting with the Dean, Dr. Yamba, presenting our experiences from Zambezi.
Furthermore, we had a meeting with Mr. Tembo from Technology Development and Advisory Unit about possibilities for co-operation, especially concerning wind-powered water pumps.

APPENDIX B

Letter from Department of Energy

to

the District Executive Secretary in Zambezi

DE/73/1/2

REPUBLIC OF ZAMBIA

DEPARTMENT OF ENERGY

P.O. BOX [illegible]
LUSAKA

1st April, 1985.

The District Executive Secretary,
P.O.Box 1,
ZAMBEZI.

Dear Sir,

Re: RURAL ENERGY SURVEY IN NORTH WESTERN PROVINCE

One of the major concerns of the Department of Energy of the Ministry of Power, Transport and Communications is energy in rural areas of Zambia. This involves the identification of specific energy problems, the running of surveys to collect information and the implementation and coordination of actions aimed at improving the energy situation and promoting rural development.

2. The Department of Energy is currently engaged in a collaboration with the Risoe National Laboratory in Denmark on a project concerned with alternative ways of providing energy in isolated areas in developing countries, such as areas which are not connected to a central electricity grid. In many places as in Zambezi, energy is provided by diesel generators which as well as being expensive because of the diesel consumption, is an unreliable solution because of difficulty of maintaining a regular supply of fuel. Alternative forms of supply, based on locally available resources, could possibly provide a cheaper and more reliable service. The choice of alternative forms of energy supply is however, a difficult one since many factors have to be taken into account. The aim of the project is to study the problems actually experienced in such an isolated area and to develop methods to help in assessing the various alternatives for energy supply.

3. Mr. John M. Christensen from Risoe National Laboratory will be visiting Zambia in the near future to work with the Department of Energy on this project. During his two-month stay in Zambia he would like to spend one month on a field study at a suitable location. For a number of reasons we have found that Zambezi would be a highly appropriate district for the field study.

4. As well as assisting Mr. Christensen in the collection of information on the local energy supply and demand situation, the Department of Energy will take this opportunity of deepening its knowledge of conditions in Zambezi, of establishing contacts and starting a concrete involvement in energy development in the district.

5. The visit to Zambezi will take place from 6th May, 1985 to 6th June. Mr. Christensen will be accompanied throughout the visit by Mr. Silvester Hitajene of the Department of Energy and for shorter periods they will be joined by Dr. G.A. Mackenzie, Mr. P. Sondergaard and Mr. M. Lagoutte, also of the Department of Energy.

6. In order to establish contact most effectively between the visitors and the relevant parties in the District it is suggested that two meetings be held, one at the beginning of the visit and one towards the end. These will have the functions of informing the local parties of the purpose of the visit, introducing the visiting personnel, discussing energy problems and possible solutions and, at the final meeting, presenting the conclusions of the study and outlining areas for future collaboration.

7. I enclose proposed agendas for the two meetings, together with a suggested list of participants. I would be most grateful if you could make the necessary arrangements for these two meetings and invite any parties whom you feel may be interested in attending and contributing. I also enclose, for your information, a copy of Mr. Christensen's Project Proposal and a copy of our letter to the Permanent Secretary, North Western Province.

8. I trust that you have no objections to the visit of Mr. Christensen and the Officers of my Department. I look forward to friendly and productive collaboration.

Yours sincerely,

Dominic Jacob Mbewe
Director
DEPARTMENT OF ENERGY

RURAL ENERGY SURVEY IN NORTH WESTERN PROVINCE

PROPOSED AGENDA FOR MEETINGS AT THE ZAMBEZI DISTRICT COUNCIL

1st Meeting: Beginning of the first week (7-10 May)

1.0 Openinng Remarks
2.0 Personal Introductions
3.0 The Role of the Department of Energy (DOE)
4.0 Plans for Rural Energy Development
5.0 Collaboration between Risoe National Laboratory of Denmark and D.O.E. of Zambia.
6.0 The Field Study and collaboration with the District Authorities.
7.0 Expected Outcome.

2nd Meeting: End of the Third Week. (20-25 May)

1.0 Opening Remarks
2.0 The situation as found
3.0 Identified possible options for Energy Development in the District.
4.0 Resources: available and required.
5.0 Future Collaboration
6.0 Vote of Thanks

N/B Attached is a list of proposed participants at these meetings. Additions of other relevant institutions are welcome.

LIST OF PARTICIPANTS

1.0 The District Council
2.0 ZESCO
3.0 Forestry Department
4.0 Department of Agriculture
5.0 Water Affairs Department
6.0 IRDP
7.0 Missions / Volunteers and other Non - Government Organisations in the area.
8.0 Education/Training Centres
9.0 Health
10.0 Industry e.g. Milling Company

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APPENDIX C

Letter from ZESCO Headoffice

to

the Technician in Charge in Zambezi

Zambia Electricity Supply Corporation Limited

Telephone. 213177
Telex ZA40150
TELEGRAMS: GENERATOR

HEADOFFICE

All Correspondence to be addressed to the General Manager

P.O. BOX 33304
LUSAKA.

Your ref. no.
Our ref. no. 4.44/1938/85

2nd May 1985

The Technician-in-Charge
Zesco Limited
P O Box 51
ZAMBEZI

Dear Sir

RE: Ph.D PROJECT ON ENERGY SUPPLY TECHNOLOGIES IN DEVELOPING COUNTRIES

The Department of Energy (Ministry of Power Transport and Comminications), in collaboration with the Risoe National Laboratory, Denmark, is involved in a project of the above title.

The aim of the project is to develop a model or tool which can be used in the comparison of alternative energy supply possibilities in isolated areas such as towns in Northwestern Province. For a number of reasons it has been found that Zambezi would be a highly suitable location for this study.

Mr John M. Christensen of the Rosie National Laboratory, will spend one month on a field study in Zambezi accompanied by officers from the Department of Energy, as from the 6th of May 1985.

In view of the importance of this project to the energy sector, the Ministry of Power Transport and Communications has requested ZESCO to cooperate in this project and assist in providing the information that may be required. It is by this letter that I wish to inform you to provide Mr Christensen with the necessary assistance he may reuire while in Zambezi. Apart from this assistance, I am kindly requesting you to provide him with LOG SHEETS of the station for the period April 1983 to March 1984, and allow him to take them to Lusaka for photocopying, these will be returned to Zambezi after two weeks.

Your cooperation to this will be greatly appreciated.

Yours faithfully,

R. Nyberg
CHIEF ENGINEER (ENGINEERING SERVICES DIVISION)

AM/pm

cc. Divisional Manager D&S (N)
cc. Acting Permanent Secretary (Ministry of Power Transport & Communication.

APPENDIX D

ZESCO's tariffs

for

isolated systems with only diesel electric power generation

Terms \ Cat.	E 1	E 2	E 3	E 4	D 1	S 1 (ZESCO-employed)
Load limits	5 A	15 A	Domestic < 15 KVA	Commercial < 15 KVA	< 300 KVA	-
Fixed charge/month	0.75 k	1.50 k	11.25 k	40.62 k	52.82 k	-
kWh charge	2.13 ng	2.13 ng	5.32 ng	5.95 ng	4.07 ng	0.8 ng
KVA charge	-	-	-	-	9.07 pr KVA	-
Deposit	13 k	25 k	63 k	88 k	indv.	50 k
Instal.	170 k	170 k	250 k	250 k	indv.	-

ZESCO - Consumer categories
Tariffs for diesel-supplied areas
(1 k = 100 ng, 1 k ≈ 5 Dkr.)

APPENDIX E

The vegetation of Zambia

Country analysis

summary

and

description of vegetation types.

(1)

Forest Department:
FAO/ZAM/4401.

WOOD CONSUMPTION STUDY
Support Study
No. 1: the Forest Areas:

ANNEX 1
THE VEGETATION OF ZAMBIA.

Types based on the system adopted for Central Africa at Yangambi, 1957.
(Correlation with Trapnell in Brackets)

TYPE		
	I	CLOSED FOREST:
		A. CLIMATIC
		1. Low and medium altitude forest
		(a) Dry evergreen forest
1		(i) Parinari forest and Copperbelt Chipya (R)
2		(ii) Marquesia forest (B1)
3		(iii) Lake Basin Chipya (B4)
4		(iv) Cryptosepalum forest (K1)
5		(v) Kalahari Sand Chipya (K11 and S)
		(b) Dry deciduous forest
6		(i) Baikiaea forest and deciduous thicket (K6,K10,L2)
7		(ii) Itigi forest (B3)
		2. High altitude forest
8		(a)Montane forest (Within E3)
		B. EDAPHIC
9		1. Swamp forest (Within SW etc
10		2. Riparian forest (Within S5 etc
	II	OPEN FOREST WITH GRASS
		A. WOODLAND
		1. Miombo woodland
11		(a) On plateau escarpment and valley soils (B2,E1E2,LP,P1 to 8, R, U1)
12		(b) On hills and rocky outcrops. (Within P1 to P8)
13		2. Kalahari woodland on sands (K2,K3,K4,K5,K7,K9,SK5)
14		3. Mopane woodland on clays. (L1, S1)
15		4. Munga woodland on heavy soils (K12,L3,R, SK1,U2,U3)
	III	TERMITARY VEGETATION AND BUSH GROUPS:
16		Termitary associated vegetation, and bush groups within grassy drainage zones (Mainly S2,S3,SK2,SK3,SK4
17	IV	GRASSLANDS: All naturally treeless and grassy areas, comprising mountain and watershed grassland, Kalahari - sand plain, dambo, flood plain, swamp and papyrus sudd. (Mainly E3,S4,S5,SK5, SK6,SP1,SP2,SP3,SW)
18		OPEN WATER:

(c)

THE VEGETATION OF ZAMBIA

(Summary and Description of the 17 vegetation Types):

Type 1. Parinari Forest: Canopy dominants are restricted to Parinari - excelsa and syzygium guineense spp afromontanum with the odd emergent Entandrophragma delevoyi.
Marquesia macroura and Erythrophleum suaveolens and occasional canopy asaociates.

Type 2. Marquesia Forest: Canopy dominants are restricted to anisophyllea pomifera, Marquesia Macroura, Podocarpus milanjianus locally and Syzygium guineense spp afromontanum

Type 3. Lake Basin Chipya: A three - storeyed woodland with an open evergr to deciduous canopy 21 to 27m high characterised by Albizia antunesian Burkea africana, Combretum collinum, Erythrophleum africanum, Parinari curatelli folia, Pericopsis angolensis, Pterocarpus - angolensis, and Terminalia sericea.
Bracken, Afrimomum and Smilax are characteristic of the forest flo

Type 4. Cryptosepalum Forest: Canopy dominants are Cryptosepalum exfeliat spp. Pseudotaxus and Guibourtia coleosperma in the lower rainfall areas but associated with Marquesia acuminata, M. Macroura, Parinari excelsa and Syzgium guineense spp. afromontanum in the higher rainfall areas.

Type 5. Kalahari Sand Chipya: Canopy Species are Burkea africanum, Combret Collinum, Dialium engleranum, Erythrophleum africanum, Guibourtia coleosperma, Peltophorum africanum Pterocarpus angolensis and Terminalia sericea and there is a dense growth of Aframomum and bracken on the forest floor.

Type 6. Baikiaea Forest: a two - storeyed forest with an open or closed, usually deciduous canopy 9 to 18m high composed of Baikiaea plurijuga and Pterocarpus antunesii in varying proportions.

Invasive Acacia gireffae and Combretum collinum are wide spread, Entandrophragma caudatum is a local emergent. Below the Canopy is a well defined deciduous thicket (Mutemwa) composed of shrubs and scramblers 3 to 6m high.

Type 7. Itigi Forest: a two storeyed forest with a very open overwood of deciduous or semi-deciduous emergents 6 to 12m high characterised by Baphia Massaiensis spp floribunda, Boscia angustifolia, Burttia prunoides, Bussea massaiensis, Diospyros mweroensis and thesucculc cactus-like Euphorbia candelabrum.

Trees are often encrusted with lichens.

Type 8. Montane Forest: A three-storeyed forest with a closed evergreen canopy about 27m high without any clear-cut dominants but with Aningeria spp., Cola greenwayi, Myrica salicifolia, Nuxia spp., Olinia usambarensis, Parinari excelsa, Podocarpus milinjianus, Rapanea melanophloea and Trichilia prieuriana as the most abundant species. Secondary montane forest is a mainly deciduous forest 2 to 18m high characterised by Hagenia abyssinnica, Macaranga Kilimandscharica, Maesa Lanceolata, and Myrica salicifolia. The ground is covered with upland grassland dotted with gnarled Protea madiensis shrubs.

Type 9. Swamp Forest: a three - storeyed forest with a closed evergreen canopy about 27m high characterised by Ilex mitis, Mitragyna Stipulosa, Syzygium cordatum, S. owariense, Xylopia aethiopica and X. rubescens.

Type 10. Riparian Forest: a three - storeyed forest with a closed, evergreen canopy 21m high characterised by Diospyros Mespiliformis, Khaya nyasica, Parinari excelsa and Syzygium cordatum associated with Adina Microcephala, Bridelia micrantha, Cleistanthus milleri, Faurea saligna, Homalium africanum, Ilex mitis, Manilkara obovata and Raphia palms.
Secondary species include Acacia polyacantha, Salix subserrata, Terminalia sericea and Ziziphus spp. Climbers are frequent.

Type 11. Miombo Woodland: a two - storeyed woodland with an open or partially closed canopy of semi-evergreen trees 15 to 21m high characterised by species of Brachystegia, Isoberlinia, Julbernardia and Marquesia macroura with Erythrophleum africanum, Parinari curatellifolia and Pericopsis angolensis as frequent associates. The forest floor is covered by a more or less dense grass cover.

Type 12. Hill Woodland: Where there is more rock than soil on the hills, the Brachystegias and their allies almost die out except for B. microphylla in the north and B. glaucescens in the south and their place is taken by hill shrubs such as Aeschynomene rubrofarinacea and A. semilunaris, Euphorbia usanguensis and E.griseola, Myrothambus flabellifolius, Pentas nobilis, Vellozia equisetoides and V. tomentossa and Vernonia bellinghamii.

Type 13. Kalahari Woodland: a two - storeyed woodland with an open or partially closed, deciduous or semi-deciduous overwood 18 to 24m high characterised by Amblygonocarpus andongensis, Burkea africana, Combretum Collinum Cyryptosepalum exfoliatum spp. Pseudotaxus, Dialium engleranum Erythrophleum africanus, Guibourtia coleosperma, Parinari curatellifolia and Terminalia sericea.

(4)

Type 14. Mopane Woodland: a one storeyed woodland with an open deciduous canopy 6 to 18m high. The dominant Colophospermum Mopane is pure or almost pure. Scattered elements of munga woodland occur here and there represented chiefly by Acacia nigrescens, Adansonia digitata, Combretum imberbe, kirkia acuminata and Lannea Stuhlmanii. Fockea multiflora is usually present.

Type 15. Munga Woodland: an open, park - like 1 to 2 storeyed deciduous woodland with scattered or grouped emergents to 18m high characterized particulary by Acacia, Combretum and Terminalia species. Occasionally it has a decidous or semi-deciduous thicket understorey.

Type 16. Termitaria Vegetation and Bush groups:
Forest, woodland, thicket, scrub and grassland vegetation types can be found on or around the bases of termitaria. Termitaria in the undermentioned vegetation types are characterized by the following species:-

(a) Miombo:- Albizia amana, Boscia angustifolia, Cassine aethiopica, Combretum molle, Commiphora mollis, Erythrina absyssinica, Euphorbia candelabrum and Ziziphus mucronata in the upper storey.

(b) Kalahari:- Boscia albitrunca, Combretum imberbe, Diospyros mespiliformis and Strychnos potatorum.

(c) Mopane:- Acacia nigrescens, Albizia harveyi, Colophospermum Mopane , Garcinia Livingstonei, Kirkia acuminata, Lannea stuhlmannii and Markhamia acuminata.

(d) Munga:- Albizia harveyi, Combretum imberbe, Lannea Stuhlmannii, Manilkara mochisia and Strychnos potatorum.

(e) Riparian:- Apodytes dimidiata, Erythrophleum suaveolens, Garcinia Livingstonei, Parinari curatellifolia and Syzygium cordatum.

(f) Bush groups: Some groups are based on termitaria along the margins of seepage dambo and flood plain.
Other bush groups are isolated patches of type 15 on slight elevations surrounded by grassland.

Type 17. Grasslands: These are associated with the drainage lines and can be divided into dambo (head water valley) grassland, riverine grassland, and flood plain grassland. These are associated with the streams and rivers.

Type 18. Other areas - mainly inland waters, lakes, dams, etc.

MB/MC
11/06/84

ANNEX II WOOD CONSUMPTION STUDY

FOREST DEPARTMENT Support Study No. 1

FAO/ZAM/4401 FOREST VEGETATION TYPES * IN ZAMBIA The Forest Area

Table 1: A Country Analysis by Province **

unit : 1000 ha

Veg Typ.	CB	NW	W	C	LUS	S	LUA	N	E	*** Tot Zambia	% of W.A	% of L.A
1	13	29								42	0.1	0.1
2								43		43	0.1	0.1
3	128	58		171			524	740	4	1625	2.7	2.2
4		952	812							1764	2.9	2.2
5			140			2				142	0.2	0.2
6		50	438	71	48	222	1	4	9	843	1.4	1.1
7							16	139		155	0.3	0.2
8		4								4	..	..
9	2	149						2		153	0.3	0.2
10		3	8	11	3	1	1	1	64	92	0.2	0.1
11	2376	5886	440	5715	1215	3295	2938	9517	2904	35286	57.7	46.9
12		5		17	324		3	11	6	366	0.6	0.5
13	19	2513	6370	36		823				9742	15.9	12.9
14		17	159	587		1019		1008	1638	4428	7.2	5.9
15	1	28	373	811	468	1044	1	81	920	3727	6.1	4.9
16	64	525	798	411	7	197	39	659	73	2773	4.5	3.7
TOT W.Area	2603	10220	9538	7829	2065	6603	3523	12205	6617	61203	100	
17	528	2362	3071	1586	122	1677	1094	2284	292	13016		17.3
18	2		31	24	2	247	437	307		1050		1.4
TOT L.Area	3133	12582	12639	9439	2189	8528	5054	14779	6911	75254		1.4
% LCT	4.2	16.7	16.8	12.5	2.9	11.3	6.7	19.6	9.2	100		100

Note:

LCT - Province area as % of Country
W.A. - Vegetation type area as % of Total Wooded area
L.A. - Vegetation type area as % of Land area
* - Based on "Vegetation map of Zambia 1976"
** - Detail available by district
*** - May not add up due to rounding

APPENDIX F

Mean daily water levels 1982 - 84

at

Zambezi Township

and

Chavuma Falls

MINISTRY OF AGRICULTURE AND WATER DEVELOPMENT

RIVER ZAMBEZI CATCHMENT ZAMBEZI

MEAN DAILY WATER LEVELS

1982/83

STATION ZAMBEZI PUMP HOUSE REF. No. 1-1.0 GAUGE ZERO 3580 (SARO)

April	May	June	July	August	September	Date
13.16	9.75	5.94	3.96	2.89		1
13.00	9.64	5.82	3.92	2.87		2
12.84	9.52	5.97	3.88	2.84		3
12.71	9.37	5.67	3.84	2.81		4
12.67	9.21	5.59	3.83	2.77		5
12.65	9.97	5.31	3.75	2.76		6
12.65	8.95	5.43	3.71	2.73		7
12.55	8.79	5.37	3.67	2.71		8
12.43	8.67	5.29	3.65	2.69		9
12.32	8.52	5.21	3.59	2.67		10
12.20	8.36	5.13	3.57	2.64		11
12.11	8.22	5.05	3.51	2.61		12
12.07	8.16	4.99	3.47	2.59		13
11.96	7.98	4.91	3.43	2.57		14
11.80	7.78	4.83	3.35	2.56		15
11.68	7.54	4.79	3.31	2.53		16
11.61	7.52	4.71	3.29	2.49		17
11.53	7.44	4.65	3.27	2.47		18
11.38	7.28	4.60	3.25	2.45		19
11.24	7.16	4.52	3.22	2.43		20
11.15	7.06	4.46	3.20	2.41		21
11.03	6.96	4.42	3.18	2.37		22
10.90	6.88	4.38	3.16	2.36		23
10.78	6.74	4.32	3.14	2.34		24
10.64	6.64	4.24	3.10	2.31		25
10.48	6.52	4.20	3.09	2.29		26
10.35	6.46	4.16	3.07	2.26		27
10.19	6.36	4.10	3.05	2.24		28
10.04	6.26	4.06	3.03	2.22		29
9.97	6.14	4.00	3.01	2.20		30
	6.04		3.00	2.18		31

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Sm D)88 3/82

MINISTRY OF AGRICULTURE AND WATER DEVELOPM

River ZAMBEZI Catchment ZAMBEZI

MEAN DAILY WATER LEVELS

19 82/83

Station ZAMBEZI PUMP HOUSE Ref. No. 1-1.5C Gauge Zero 5382 (BAC

Date	October	November	December	January	February	March
1		2.35	3.88	8.46	9.48	13.99
2		2.37	4.10	8.60	9.68	13.87
3		2.40	4.26	3.61	9.94	13.75
4		2.45	4.42	8.58	10.3	13.60
5		2.45	4.56	8.58	10.5	13.46
6		2.45	4.71	8.38	10.7	13.28
7		2.45	4.93	8.18	10.8	13.10
8		2.55	5.13	8.04	10.9	12.95
9		2.64	5.49	7.94	11.1	12.84
10		2.66	5.75	7.92	11.2	12.78
11		2.58	6.06	7.96	11.6	12.72
12	RECORDS	2.56	6.22	7.98	11.7	12.57
13		2.52	6.36	8.08	11.9	12.41
14		2.47	6.54	8.16	12.2	12.33
15		2.44	6.84	8.26	12.5	12.32
16	NO	2.50	7.20	8.40	12.8	12.37
17		2.50	7.42	8.56	13.0	12.37
18		2.48	7.50	8.65	13.2	12.37
19		2.52	7.55	8.65	13.3	12.39
20		2.67	7.64	8.65	13.4	12.43
21		2.80	7.74	8.73	13.5	12.39
22		2.88	7.79	8.83	13.6	12.45
23	1.94	2.97	7.80	8.95	13.7	12.61
24	2.00	2.92	7.83	9.09	13.8	12.86
25	2.10	3.02	7.84	9.23	13.9	13.02
26	2.15	3.20	7.84	9.37	14.0	13.12
27	2.25	3.50	7.84	9.39	14.0	13.22
28	2.25	3.61	7.88	9.42	14.0	13.28
29	2.25	3.69	7.94	9.48		13.32
30	2.28	3.79	8.06	9.45		13.35
31	2.30		8.26	9.40		13.28

Hydro. 95/1b

MINISTRY OF AGRICULTURE AND WATER DEVELOPMENT

River ZAMBEZI Catchment ZAMBEZI

MEAN DAILY WATER LEVELS

1983/84

Station ZAMBEZI PUMP HOUSE Ref. No. 1-1.5.D. Gauge Zero 3380 (RAR)

April	May	June	July	August	September	Date
	13.16	6.74	4.14	2.47		1
	12.94	6.64	4.06	2.42		2
	12.76	6.52	3.98	2.37		3
	12.58	6.40	3.94	2.34		4
	12.35	6.28	3.90	2.31		5
	12.15	6.19	3.84	2.28		6
	11.92	6.04	3.75	2.27		7
	11.65	5.96	3.70	2.21		8
	11.41	5.87	3.67	2.16		9
	11.13	5.77	3.63	2.11		10
	10.83	5.65	3.57	2.08		11
	10.59	5.59	3.58	2.06		12
	10.32	5.51	3.47	2.03		13
	10.05	5.37	3.43	2.00		14
	9.78	5.29	3.41	1.97		15
	9.54	5.21	3.36	1.92		16
	9.31	5.15	3.10	1.87		17
	9.07	5.09	3.05	1.84		18
	8.87	5.00	3.00	1.82		19
	8.62	4.85	2.98	1.79		20
	8.44	4.77	2.94	1.74		21
	8.23	4.73	2.91	1.69		22
	8.00	4.65	2.89	1.67		23
	7.88	4.62	2.87	1.64		24
	7.72	4.54	2.78	1.62		25
	7.56	4.52	2.70	1.61		26
	7.42	4.42	2.68			27
	7.27	4.30	2.60	G.P washed		28
	7.15	4.25	2.59	away		29
	6.99	4.20	2.57			30
	6.84		2.57			31

Form D388 3/82 INCLINED GAUGE Hy.

MINISTRY OF AGRICULTURE AND WATER DEVELOPME.

River ZAMBEZI Catchment ZAMBEZI

MEAN DAILY WATER LEVELS

1983/84

Station ZAMBEZI PUMP HOUSE Ref. No. 1-1820 Gauge Zero 3382 (BAR)

Date	October	November	December	January	February	March
1			1.85	4.73	13.34	26.94
2			1.85	4.81	14.04	26.77
3			1.90	4.97	14.67	26.64
4			1.95	5.13	15.17	26.60
5			1.95	5.29	15.88	26.63
6			2.05	5.56	16.22	26.60
7			2.05	5.61	16.93	26.44
8			2.25	5.73	17.57	26.23
9			2.25	5.83	18.05	26.06
10			2.35	5.99	18.65	25.90
11			2.35	6.16	19.10	25.49
12			2.45	6.03	19.54	25.22
13			2.45	6.48	20.02	24.94
14			2.45	6.59	20.37	24.67
15			2.45	6.82	20.72	24.45
16			2.55	7.34	21.14	24.14
17			2.55	8.00	21.72	23.82
18			2.75	8.39	22.36	23.40
19			2.85	9.11	22.86	22.94
20			3.05	9.66	23.29	22.63
21			3.15	10.72	24.06	22.42
22			3.43	10.76	24.91	22.30
23			3.62	11.30	25.72	22.30
24			3.79	11.69	26.16	22.20
25			4.04	12.12	26.77	21.93
26			4.33	12.53	26.96	21.69
27			4.44	12.77	27.07	21.49
28			4.56	12.86	27.12	21.23
29			4.62	12.86	27.08	20.95
30			4.67	12.84		20.76
31			4.69	12.94		20.67

Hydro. 95.1a

MINISTRY OF AGRICULTURE AND WATER DEVELOPMENT

River ZAMBEZI Catchment ZAMBEZI

MEAN DAILY WATER LEVELS

19 84/85

Station ZAMBEZI PUMP HOUSE Ref. No. 1-150 Gauge Zero ARB

Date	October	November	December	January	February	March
1			2.45	[illegible]	8.27	
2			2.45	5.71	8.40	
3			2.50	[illegible]	8.57	
4			2.55	6.00	8.89	
5			2.60	6.06	9.25	
6			2.70	6.14	9.57	
7			2.75	6.22	9.90	
8			2.85	6.28	10.25	
9			2.95	6.38	10.75	
10			3.05	6.44	11.30	
11			3.15	6.45	11.77	
12			3.25	6.46	12.22	
13			3.43	6.55	12.63	
14			3.55	6.82	13.30	
15			3.66	7.02	13.84	
16			3.70	7.22	14.20	
17			3.93	7.38	14.49	
18			4.06	7.52	14.62	
19			4.26	7.60	14.76	
20			4.50	7.65	14.89	
21			4.69	7.75	14.94	
22			4.79	7.79	14.95	
23			4.89	[illegible]	14.90	
24			5.03	7.86	14.82	
25			5.17	7.90	14.93	
26			5.28	7.92	14.98	
27			5.39	[illegible]	14.91	
28			5.49	[illegible]	14.98	
29			5.61	[illegible]		
30			5.71	[illegible]		
31			5.77	8.26		

Initials .....

No. D167 3/82 Hydro 95:1b

MINISTRY OF AGRICULTURE AND WATER DEVELOPMENT

River ZAMBEZI Catchment ZAMBEZI

MEAN DAILY WATER LEVELS

1982/83

Station CHAVUMA FALLS Ref. No. 1-105 Gauge Zero ARBITRARY

April	May	June	July	August	September	Date
13.90	11.60	7.60	5.20	3.40	1.90	1
13.75	11.55	7.50	5.15	3.35	1.80	2
13.60	11.30	7.40	5.10	3.30	1.80	3
13.50	11.20	7.30	5.00	3.20	1.70	4
13.60	11.10	7.20	4.95	3.20	1.65	5
13.60	10.90	7.10	4.90	3.10	1.60	6
13.50	10.80	7.00	4.85	3.10	1.50	7
13.40	10.65	6.90	4.80	3.00	1.50	8
13.35	10.95	6.80	4.70	3.00	1.40	9
13.30	10.30	6.70	4.70	2.90	1.30	10
13.20	10.15	6.60	4.60	2.90	1.30	11
13.10	9.95	6.50	4.60	2.80	1.30	12
13.15	9.85	6.40	4.50	2.80	1.20	13
13.00	9.75	6.30	4.50	2.80	1.20	14
12.90	9.65	6.20	4.40	2.70	1.10	15
12.85	9.40	6.20	4.40	2.70	1.10	16
12.80	9.30	6.10	4.30	2.60	1.00	17
12.70	9.15	6.10	4.30	2.60	1.00	18
12.60	9.05	6.10	4.20	2.50	0.99	19
12.55	8.90	5.90	4.10	2.50	0.99	20
12.50	8.80	5.90	4.10	2.40	0.97	21
12.45	8.70	5.80	4.00	2.40	0.87	22
12.40	8.60	5.70	4.00	2.30	0.70	23
12.30	8.50	5.70	3.90	2.20	0.65	24
12.20	8.40	5.60	3.80	2.20	0.60	25
12.10	8.30	5.60	3.75	2.10	0.53	26
12.00	8.20	5.50	3.70	2.10	0.50	27
11.85	8.05	5.40	3.60	2.00	0.50	28
11.70	7.90	5.40	3.60	2.00	0.52	29
11.65	7.80	5.30	3.50	1.95	0.50	30
	7.70		3.50	1.90		31

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Form D386 3/82

MINISTRY OF AGRICULTURE AND WATER DEVELOPM.

River ZAMBEZI Catchment ZAMBEZI

MEAN DAILY WATER LEVELS

1982.83

Station CHAVUMA FALLS Ref. No. 1-105 Gauge Zero ARBITRARY

Date	October	November	December	January	February	March
1	1·50	3·06	5·55	10·50	11·40	14·50
2	1·47	3·10	5·60	10·60	11·40	14·40
3	1·43	3·10	6·05	10·55	11·80	14·30
4	1·39	3·10	6·30	10·35	11·70	14·20
5	1·33	3·00	6·25	10·20	11·80	14·10
6	1·30	3·00	6·45	10·25	12·40	14·00
7	1·30	3·08	6·70	10·05	12·55	13·90
8	1·30	3·10	6·85	9·90	12·70	13·80
9	1·30	3·10	7·90	9·80	12·80	13·70
10	1·30	3·00	7·80	9·85	12·85	13·60
11	1·30	3·00	17·95	10·00	12·95	13·50
12	1·30	3·00	8·10	10·10	13·05	13·40
13	1·30	2·90	18·20	10·15	13·20	13·30
14	1·30	2·80	8·60	10·45	13·30	13·20
15	1·30	2·85	9·05	10·35	13·70	13·15
16	1·30	2·90	9·25	10·65	13·80	13·35
17	1·42	2·90	9·35	10·45	13·85	13·40
18	1·58	3·10	19·30	10·60	13·90	13·30
19	1·72	3·30	9·50	10·55	14·10	13·20
20	1·83	3·40	9·60	10·55	14·20	13·15
21	1·87	3·45	9·60	10·75	14·30	13·40
22	1·94	3·50	9·60	11·00	14·40	13·55
23	2·05	3·55	9·60	11·20	14·50	13·75
24	2·21	3·70	9·60	11·15	14·55	13·90
25	2·40	4·25	9·65	11·05	14·60	14·00
26	2·58	4·70	9·70	11·25	14·65	14·05
27	2·58	4·70	9·75	11·40	14·70	14·10
28	2·58	4·80	9·85	11·45	14·60	14·20
29	2·58	4·90	10·00	11·25		14·10
30	2·60	5·10	10·20	11·40		14·05
31	2·60		10·50	11·30		14·00
	325					

Hydro. 75/1b

MINISTRY OF AGRICULTURE AND WATER DEVELOPMENT

River ZAMBEZI Catchment ZAMBEZI

MEAN DAILY WATER LEVELS

19 83/84

Station CHAVUMA FALLS Ref. No. 1-1.05 Gauge Zero ARBITRARY

April	May	June	July	August	September	Date
	13·80			3·20		1
	13·70			3·10		2
	13·60			3·10		3
	13·35			3·00		4
	13·15			3·00		5
	13·00			2·90		6
	12·85			2·90		7
	12·65			2·80		8
	12·45			2·80		9
	12·25			2·70		10
	12·15			2·70		11
	11·90			2·60		12
	11·75			2·50		13
	11·45			2·45		14
	11·25			2·40		15
	11·05			2·35		16
	10·85			2·30		17
	10·65			2·20		18
	10·45			2·15		19
	10·15			2·10		20
	10·00			2·00		21
	9·85			2·00		22
	9·65			2·00		23
	9·45			1·90		24
	9·25			1·90		25
	9·10			1·80		26
	9·00			1·80		27
	8·85			1·70		28
	8·65			1·70		29
	8·50			1·65		30
	8·40			1·60		31

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MINISTRY OF AGRICULTURE AND WATER DEVEL...

RIVER ZAMBEZI CATCHMENT ZAMBEZI

MEAN DAILY WATER LEVELS

19 83/84

STATION CHAVUMA FALLS REF. NO. 1-1.05 GAUGE ZERO ARBITRARY

Date	October	November	December	January	February	March
1	0·47	1·35	2.05	6·75	14·15	22.15
2	0.40	1·30	2.20	7·00	14·90	22.05
3	0.40	1·40	2.35	6·95	15·20	22.10
4	0·30	1·35	2.70	7·10	15·85	22.10
5	0·30	1·20	2.80	7·40	16·25	22.20
6	0·20	1·20	2.60	7·40	16·45	22.10
7	0·20	1·30	2.75	7·60	16·75	22.00
8	0·20	1·40	3.05	7·75	17·15	21·80
9	0·10	1·50	3·00	7·95	17·40	21·45
10	0·10	1·55	3·10	8·15	17·75	21·25
11	0·10	1·60	3·20	8·35	17·90	21·10
12	0·10	1·65	3·15	8·55	18·25	21·00
13	0·00	1·70	3·05	8·65	18·50	21·85
14	0·00	1·80	3·20	9·00	18·65	20·75
15	0.00	1·70	3·30	9·80	19·00	20·60
16	0·10	1·65	3·40	10·05	19·30	20·35
17	0·20	1·60	3·55	10·45	19·70	20·10
18	0·10	1·50	3·85	10·75	19·95	19·80
19	0·10	1·55	4·30	11·70	20·25	19·55
20	0·20	1·60	4·55	12·10	20·45	19·30
21	0·20	1·70	4·95	12·45	20·80	19·45
22	0·20	1·80	5·30	12·80	21·85	19·60
23	0·30	2.00	5·70	13·15	22.40	19·45
24	0·30	2.10	6.20	13·35	22.65	19·25
25	0·60	2.10	6·50	13·65	22.60	19·10
26	0·80	2.05	6·50	13·85	22.70	19·10
27	0·90	2.10	6·50	13·80	22.80	18·85
28	1·20	2.10	6·55	13·80	22.54	18·65
29	1·20	2.10	6·65	13·80	20.35	18·35
30	1·30	2.05	6·65	13·90		18·15
31	1·40		6·60	13·95		18·55

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MINISTRY OF AGRICULTURE AND WATER DEVELOPMENT

River ZAMBEZI Catchment ZAMBEZI

MEAN DAILY WATER LEVELS

1984/85

Station CHANYUMA FALLS Ref. No. 1.105 Gauge Zero ARB

Date	October	November	December	January	February	March
1	0.03	0.60	2.95	7.60	10.25	
2	0.03	6.70	3.10	7.65	10.45	
3	0.02	0.80	3.25	7.70	10.75	
4	0.02	0.90	3.37	7.75	11.10	
5	0.01	0.90	3.43	7.85	11.10	
6	0.02	1.00	3.52	8.00	11.30	
7	0.02	1.00	3.62	7.90	11.90	
8	0.03	1.00	3.92	8.00	12.30	
9	0.03	1.15	3.80	8.10	12.80	
10	0.03	1.25	4.13	8.00	13.10	
11	0.03	1.35	4.27	8.10	13.35	
12	0.03	1.63	4.32	8.20	13.70	
13	0.04	1.72	4.60	8.55	14.05	
14	0.04	1.77	4.93	8.90	14.25	
15	0.04	1.84	5.25	9.10	14.55	
16	0.05	1.92	5.45	9.25	14.80	
17	0.05	2.03	5.70	9.45	14.90	
18	0.06	2.13	5.85	9.60	14.90	
19	0.06	2.22	6.15	9.70	15.00	
20	0.06	2.37	6.25	9.70	15.00	
21	0.06	2.53	6.50	9.75	15.10	
22	0.06	2.65	6.65	9.80	15.05	
23	0.06	2.65	6.80	9.85	15.00	
24	0.06	2.65	6.90	9.80	15.00	
25	0.06	2.68	6.90	9.90	14.90	
26	0.06	2.68	7.00	9.90	15.05	
27	0.06	2.68	7.15	10.00	15.25	
28	0.06	2.70	7.30	10.05	15.25	
29	0.06	2.70	7.40	10.15		
30	0.05	2.80	7.50	10.20		
31	0.05		7.60	10.20		

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APPENDIX G

Summary of Household Energy Consumption Survey

G.1. Data analysis

It is impossible to compare the energy consumption of the different household categories without converting the figures listed in chapter 5 to comparable terms. In order to be able to compare the direct end-use consumption figures, the following conversion factors have been used

Wood (air dried)	:	0.0155 GJ/kg
Charcoal	:	0.0326 GJ/kg
Kerosene	:	0.0351 GJ/L
Electricity	:	0.0036 GJ/kWh
Diesel	:	0.0387 GJ/L

From chapter 5 the following average consumption figures can be calculated:

Table G.1. Average family size and consumption figures - households

Average values	Family size	Electricity kWh	Charcoal kg	Firewood kg	Kerosene L
High income	5.4	3736.36	583.64	331.82	0.00
Middle income	8.1	613.50	861.00	1831.50	0.00
Low income	7.3	0.00	635.63	2028.44	38.88
Subsistence	6.1	0.00	160.59	2822.35	25.12

Using the listed factors the figures in table G.1 can be converted to standard energy terms.

Table G.2. End-use energy consumption - households

Tot. energy (GJ)	Elec-tricity	Char-coal	Fire-wood	Kero-sene	Total energy consumption	Energy per capita
High income	13.45	19.03	5.14	0.00	37.62 GJ/year	7.60 GJ/year
Middle income	2.21	28.07	28.39	0.00	58.67 -	7.37 -
Low income	0.00	20.72	31.44	1.36	53.53 -	7.49 -
Subsistence	0.00	5.24	43.75	0.88	49.86 -	9.80 -

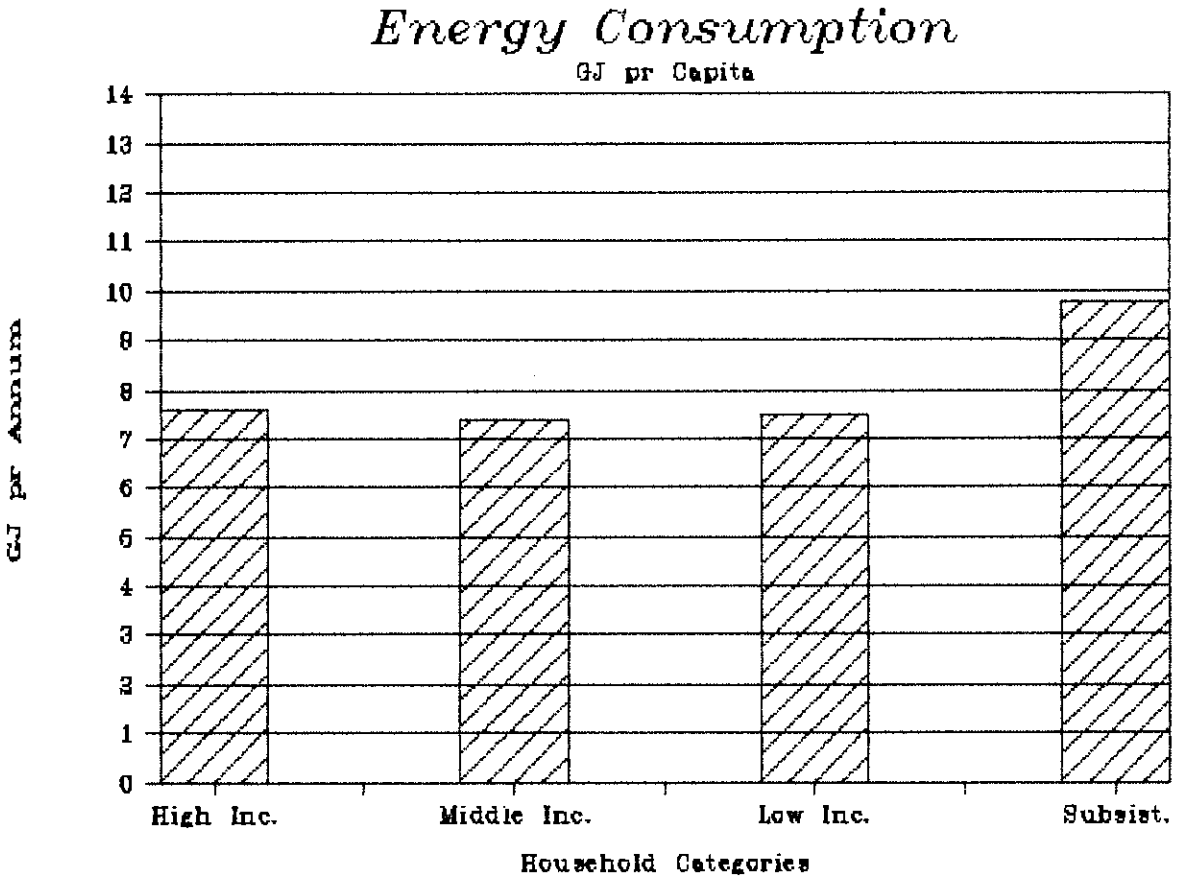

Fig. G.3. Per capita end-use energy consumption

G.2. End-use consumption

It is evident from Fig. G.3, that the average end-use consumption in the three cash income groups are almost alike, while

the subsistence households use about 30% more. It is probably a bit of a coincidence that the three groups are so alike. One explanation is that the higher income groups have a better utilization of their sources especially the electricity, and therefore actually "use" more energy, while the lower income groups cover a larger part of their consumption with firewood, where the direct efficiency e.g. for cooking is about 10% of the energy content. This is also the reason why the figure for per capita energy consumption is higher for the subsistence households, where firewood is the totally dominant source.

To illustrate the relation between the income level and the choice of energy source, the following four figures show the percentage share that each source covers of the average end-use energy consumption for the four household categories.

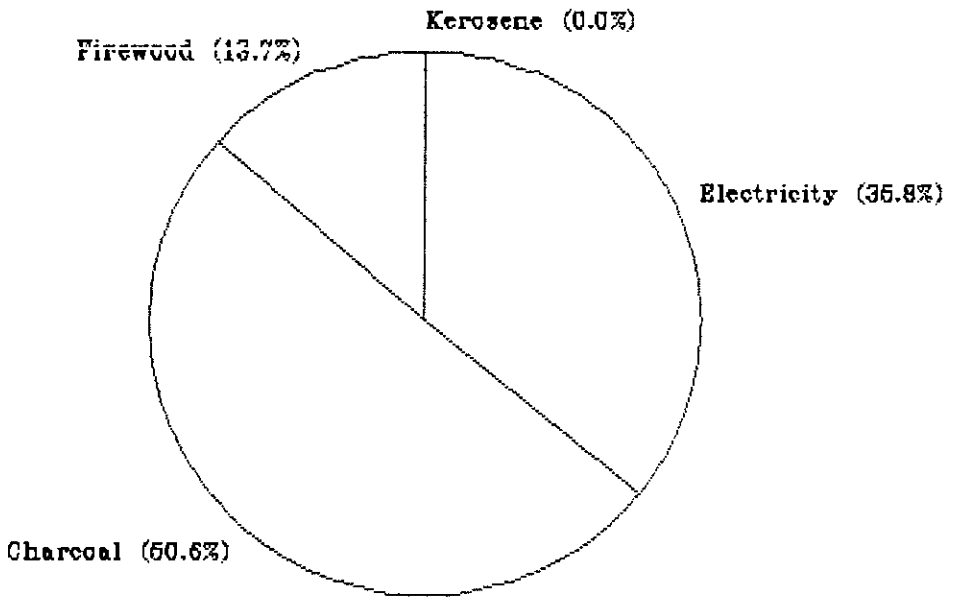

Fig. G.4. End-use consumption by source - high income households

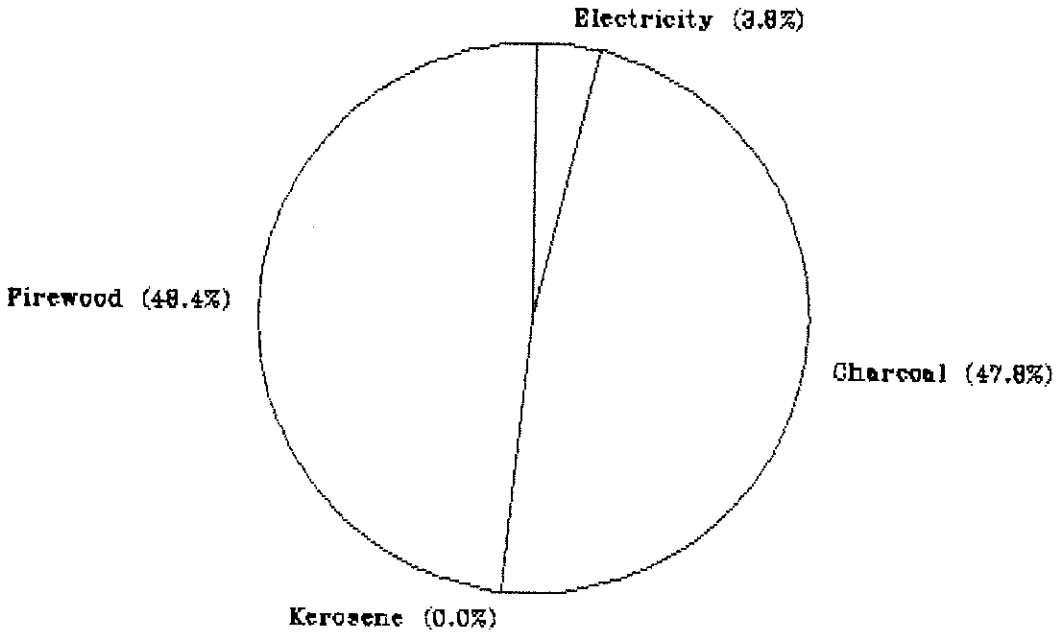

Fig. G.5. End-use consumption by source - middle income households

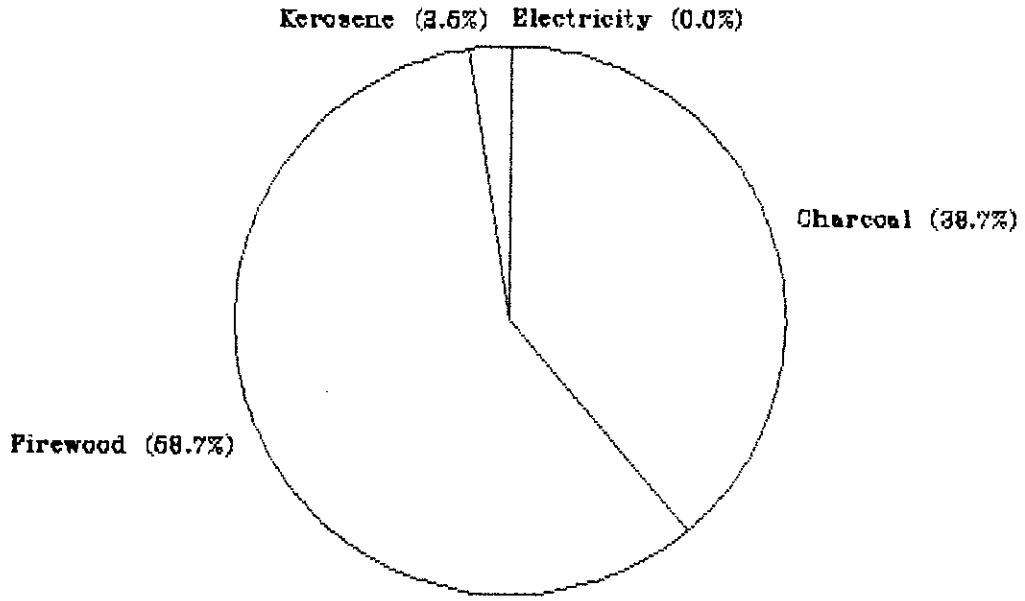

Fig. G.6. End-use consumption by source - low income households

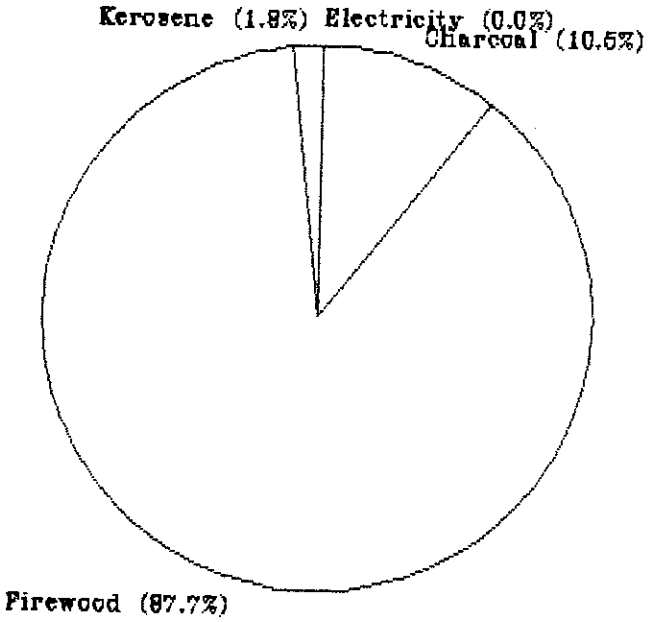

Fig. G.7. End-use consumption by source - subsistence households

G.3. Resource consumption

In the previous section energy consumption is analyzed from a consumers point of view. Looking at the rural energy situation from a national institution like DOE, it is also relevant to consider the various losses that occur in the different conversion processes.
Our estimates of the relevant conversion efficiencies for Zambezi are

Wood	to Charcoal	: 0.125 kg charcoal per kg wood
Diesel	to Electricity	: 0.4 L diesel per produced kWh

and the loss in the electricity distribution system is 10%. In order to keep to the direct losses, things like transport costs and the minor losses by the loading and unloading processes have been neglected.

Based on the same consumption figures in Table G.1, we can now find the energy consumption, as it is, when the conversion losses are included:

Table G.8. Average energy resource consumption

Tot. energy (GJ)	Elec-tricity	Char-coal	Fire-wood	Kero-sene	Total energy consumption	Energy per capita
High income	64.27	72.37	5.14	0.00	141.78 GJ/year	28.48 GJ/year
Middle income	10.55	106.76	28.39	0.00	145.70 -	18.60 -
Low income	0.00	78.82	31.44	1.36	111.62 -	17.31 -
Subsistence	0.00	19.91	43.75	0.88	64.54 -	12.89 -

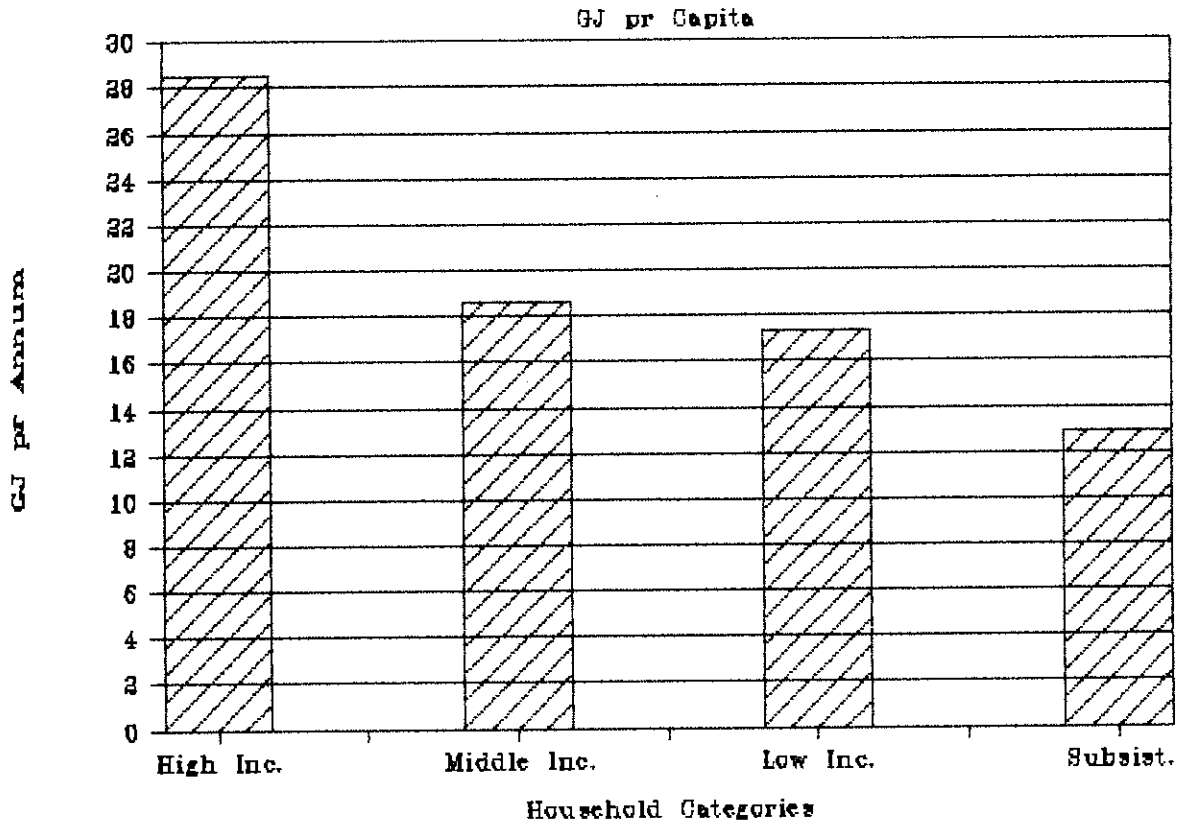

Fig. G.9. Per capita energy resource consumption

This way of analyzing the per capita consumption supports the explanation about resource and user efficiency given in the last section. Due to the low efficiency of the local diesel power station the tendency is a bit exaggerated. It is, however, obvious that although the subsistence households have the largest end-use consumption, their total use of resources are the lowest among the four household categories.

Another interesting information that can be extracted from the figures in Table G.8 is that charcoal due to the very low efficiency in the conversion process represents a very large part of the energy resource consumption for all four household categories. This is shown in the Figures G.10 - 13 that are similar to G.4 - 7 just with the conversion efficiencies included.

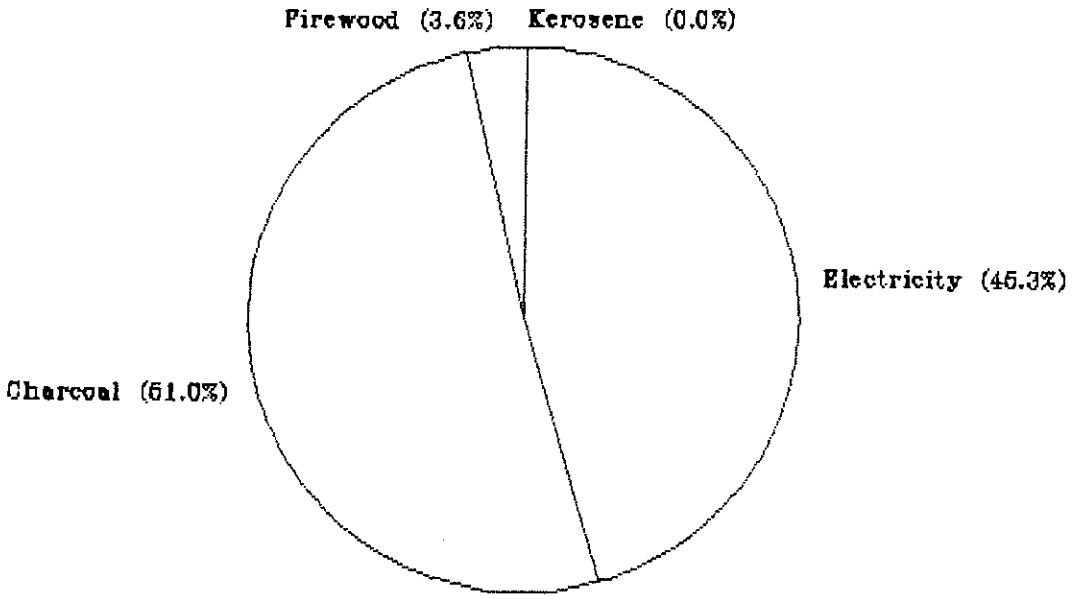

Fig. G.10. Energy resource consumption - high income households

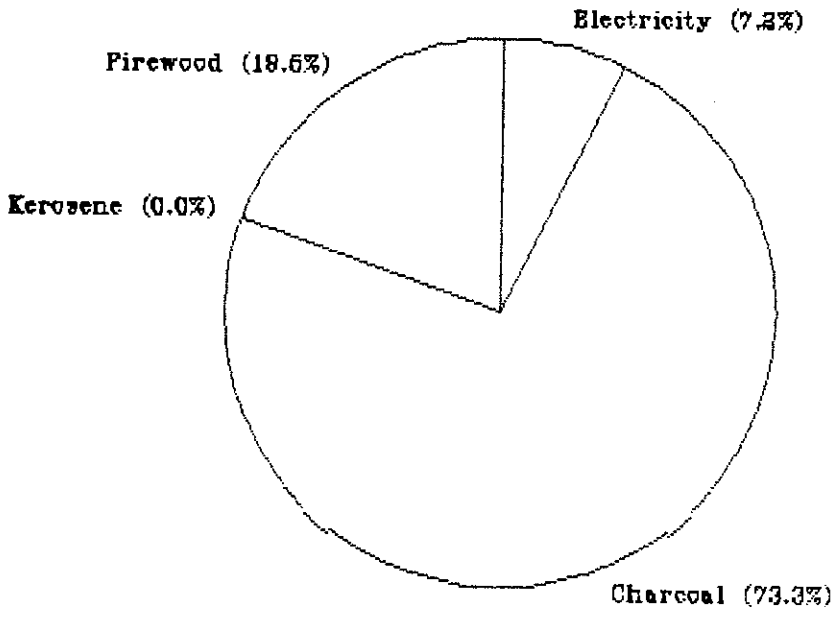

Fig. G.11. Energy resource consumption - middle income households

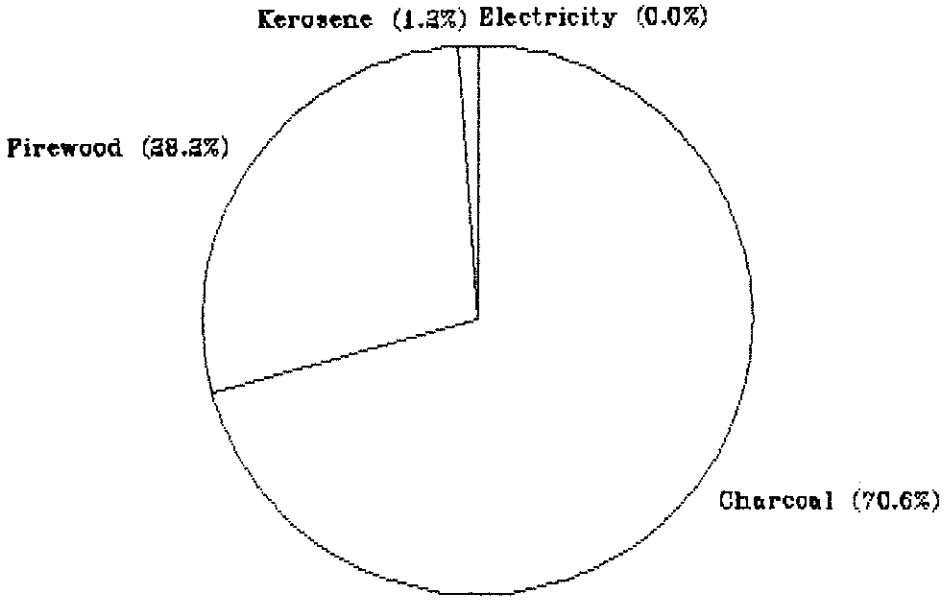

Fig. G.12. Energy resource consumption - low income households

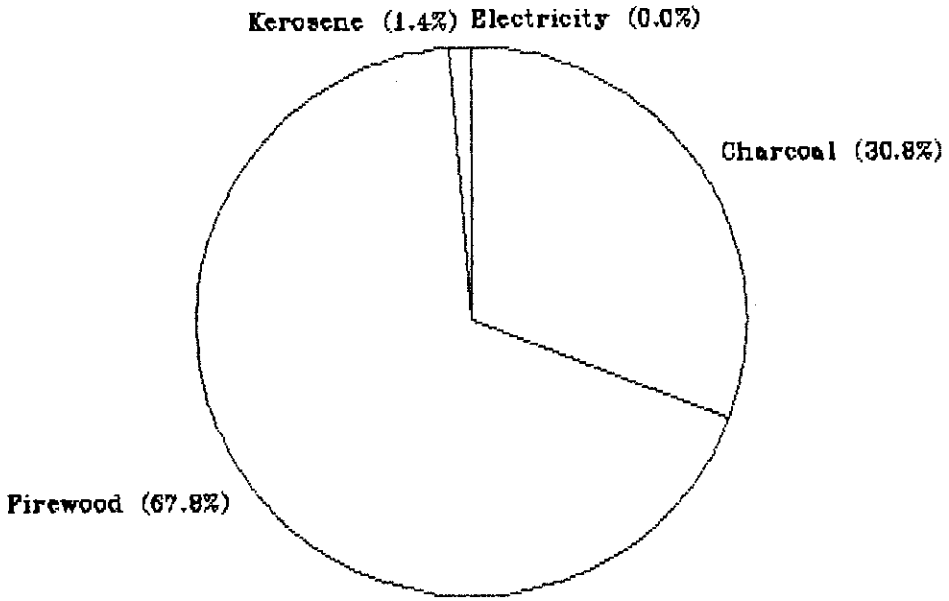

Fig. G.13. Energy resource consumption - subsistence households

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Title and author(s)

Energy survey in Zambezi.
Report from a study in Zambia - 1985

John M. Christensen

Date October 1985

Department or group
Energy Systems Group

Group's own registration number(s)

116 pages + 16 tables + 36 illustrations

Abstract

The report presents the results and experiences from a field study in Zambia. The energy situation is described in detail. Energy consumption is analyzed by end-use and source. The supply situtation for the different sources - firewood, charcoal, kerosene and electricity is presented and the available local and renewable resources are outlined.
The household sector is divided into subsectors and the relation between income level and the choice of energy source is studied in detail.

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